U.S. DEPARTMENT OF COMMERCE
National Technical Information Service

PB-256 502

Alternative Waste Management Techniques for Best Practicable Waste Treatment. Proposed for Public Comment

Environmental Protection Agency

March 1974

BEST SELLERS

FROM
NATIONAL TECHNICAL INFORMATION SERVICE

Comparison of Energy Consumption Between West Germany and the United States
PB-245 652/ PAT 112 p. PC$5.50/MF$3.00

A Comprehensive Policy to Ameliorate Adverse Impacts of Transportation Facilities
PB-247 823/ PAT 138 p. PC$6.00/MF $3.00

A Comprehensive Policy to Ameliorate Adverse Impacts of Transporation Facilities, Appendix
PB-247 824/ PAT 310 p. PC$9.75/MF$3.00

Demand for Coal for Electricity Generation 1975–1984
PB-245 216/ PAT 40 p. PC$4.00/MF$3.00

A National Study of Adolescent Drinking Behavior, Attitudes and Correlates
PB-246 002/ PAT 405 p. PC$11.00/MF $3.00

Energy from Coal: Guidelines for the Preparation of Environmental Impact Statements
PB-242 960/ PAT 258 p. PC$9.00/MF $3.00

Energy Versus the Environment: The Issues
PB-246 382/ PAT 35 p. PC$4.00/MF $3.00

Improving the Dissemination of Scientific and Technical Information: A Practitioner's Guide to Innovation
PB-247 057/ PAT 203 p. PC$7.75/MF $3.00

Investigation and Evaluation of Cracking in Austenitic Stainless Steel Piping of Boiling Water Reactor Plants
PB-246 645/ PAT 123 p. PC$5.50/MF $3.00

Pipeline Industry's Practices Using Plastic Pipe in Gas Pipeline Facilities and the Resulting Safety Factors
PB-247 301 / PAT 436 p. PC$11.75/MF $3.00

NOx Combustion Control Methods and Costs for Stationary Sources. Summary Study.
PB-246 750/ PAT 117 p. PC$5.50/MF$3.00

Reactor Safety Study: An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants
PB-248 200/SET/ PAT 2,504 p. 8 Volumes PC$61.00

Report on Sulfur Oxide Control Technology
PB-246 667/ PAT 89 p. PC$5.00/MF$3.00

Research Evaluation of a System of Natural Air Conditioning
PB-243 498/ PAT 364 p. PC$10.50/MF$3.00

Retrofitting a Residence for Solar Heating and Cooling: The Design and Construction of the System
PB-247 482/ PAT 101 p. PC$5.50/MF$3.00

Saudi Arabia Five-Year Plan, 1975–1980
PB-246 572/ PAT 683 p. PC$16.25/MF$3.00

Shotcrete Practice in Underground Construction
PB-248 765/ PAT 501 p. PC$12.75/MF $3.00

Short-Term Coal Forecast, 1975–1980
PB-247 073/ PAT 120 p. PC$5.50/MF$3.00

State Energy Information Systems: A Survey
PB-247 457/ PAT 64 p. PC$4.50/MF$3.00

A Study of Fixed Capital Requirements of the U.S. Business Economy
PB-248 690/ PAT 84 p. PC$5.00/MF $3.00

Sulfates and the Environment—A Review
PB-248 122/ PAT 155 p. PC$6.75/MF $3.00

HOW TO ORDER

When you indicate the method of payment, please note if a purchase order is not accompanied by payment, you will be billed an addition $5.00 *ship and bill* charge. And please include the card expiration date when using American Express.

Normal delivery time takes three to five weeks. It is vital that you order by number or your order will be manually filled, insuring a delay. You can opt for *airmail delivery* for a $2.00 charge per item. Just check the *Airmail Service* box. If you're really pressed for time, call the NTIS Rush Order Service. (703) 557-4700. For a $10.00 charge per item, your order will be airmailed within 48 hours. Or, you can pick up your order in the Washington Information Center & Bookstore or at our Springfield Operations Center within 24 hours for a $6.00 per item charge.

You may also place your order by telephone or TELEX. The order desk number is (703) 557-4650 and the TELEX number is 89-9405.

Whenever a foreign sales price is NOT specified in the listings, all foreign buyers must add the following charges to each order: $2.50 for each paper copy; $1.50 for each microfiche; and $10.00 for each Published Search.

Thank you for your interest in NTIS. We appreciate your order.

METHOD OF PAYMENT

☐ Charge my NTIS deposit account no.__________
☐ Purchase order no.__________
☐ Check enclosed for $__________
☐ Charge to my American Express Card account number

☐☐☐☐☐☐☐☐☐☐☐☐☐☐☐

Card expiration date__________
Signature__________
☐ Airmail Services requested

NAME__________
ADDRESS__________
CITY, STATE, ZIP__________

Item Number	Quantity		Unit Price*	Total Price*
	Paper Copy (PC)	Microfiche (MF)		

* All Prices Subject to Change
8/76

Sub Total	
Additional Charge	
Enter Grand Total	

Clip and mail to:

NTIS
National Technical Information Service
U.S. DEPARTMENT OF COMMERCE
Springfield, Va. 22161
(703) 557-4650 TELEX 89-9405

217059

00 1822

PB 256 502

ALTERNATIVE WASTE MANAGEMENT TECHNIQUES FOR BEST PRACTICABLE WASTE TREATMENT

PROPOSED FOR PUBLIC COMMENT

MARCH 1974

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Water Program Operations
Washington, D.C. 20460

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U. S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

BIBLIOGRAPHIC DATA SHEET

1. Report No.

2.

3. Recipient's Accession No.
PB-256 502

4. Title and Subtitle
Alternative Waste Management Techniques for
Best Practicable Waste Treatment.
Proposed for Public Comment.

5. Report Date
March 1974

6.

7. Author(s)

8. Performing Organization Rept. No.

9. Performing Organization Name and Address
Environmental Protection Agency
Washington, D. C.
Office of Water Program Operations

10. Project/Task/Work Unit No.

11. Contract/Grant No.

12. Sponsoring Organization Name and Address

13. Type of Report & Period Covered

14.

15. Supplementary Notes

16. Abstracts

Contents:
Introduction with Statutory requirements and legislative history; Waste management techniques involving land application or land utilization; Waste management techniques involving treatment and discharge; Reuse techniques.

17. Key Words and Document Analysis. 17a. Descriptors

*Water pollution abatement
*Water quality management
Statutes
Legislation
Management
Land use
Irrigation
Sewage
Fluid infiltration
Industrial waste treatment
Waste disposal
Sludge disposal
Percolation
Waste water reuse
Earth fills
Incinerators
Fly ash
Sewage treatment

17b. Identifiers/Open-Ended Terms

*Sewage irrigation
*Landfills
*Overland flow
*Best technology
Alternative planning

17c. COSATI Field/Group 13B, 2C

18. Availability Statement
National Technical Information Service
Springfield, VA 22161

19. Security Class (This Report)
UNCLASSIFIED

20. Security Class (This Page)
UNCLASSIFIED

21. No. of Pages
133

22. Price PC$6.00/
MF$2.25

FORM NTIS-35 (REV. 10-73) ENDORSED BY ANSI AND UNESCO. THIS FORM MAY BE REPRODUCED USCOMM-DC 8265-P74

ALTERNATIVE WASTE MANAGEMENT TECHNIQUES FOR BEST PRACTICABLE WASTE TREATMENT

TABLE OF CONTENTS

I. Introduction I-1

A. Statutory Requirements I-1

B. Legislative History I-2

C. Summary of Conclusions I-3

II. Waste Management Techniques Involving Land Application or Land Utilization II-1

A. Land Application Techniques II-5

Irrigation II-5
Overland Flow II-14
Infiltration-Percolation II-17
Other Land Application Techniques II-20

B. Land Utilization Techniques II-20

Land Spreading of Sludge II-20
Landfill of Sludge II-21
Landfill of Incinerator Ash II-21
Composting and Final Disposal II-22

C. Non-Point Sources of Pollutants II-22

III. Waste Management Techniques Involving Treatment and Discharge III-1

A. Flow Reduction III-12

2<

B. Techniques to Achieve Secondary Treatment and Nitrification III-14

  Biological III-14

  a. Ponds III-15

  b. Activated Sludge III-15

  c. Trickling Filters III-17

  Physical-Chemical III-17

  Land Application III-18

C. Storm and Combined Sewer Control III-18

  Separation of Combined Sewers III-19
  Control of Combined Sewers III-19
  Storage and Treatment of Combined Overflows III-22
  Dual Use III-22
  Treatment of Combined Overflows III-23

D. Advanced Waste Treatment (Nutrient Removal) III-23

  Biological III-24

  Physical-Chemical III-24

  Land Application III-25

IV. Reuse Techniques IV-1

A. Reuse of Wastewater IV-1

B. Reuse of Other Treatment-Plant Wastes IV-2

C. Integrated Reuse Facilities IV-3

35

Appendix A - Bibliography

- I. General Information
- II. Land Application Techniques
- III. Land Utilization Techniques
- IV. Flow Reduction
- V. Ponds
- VI. Activated Sludge
- VII. Trickling Filters
- VIII. Physical-Chemical Treatment
- IX. Storm and Combined Sewers
- X. Advanced Waste Treatment
- XI. Reuse Techniques

Appendix B - Cost-Effectiveness Analysis Guidelines (40 CFR 35)

Appendix C - Secondary Treatment Information (40 CFR 133)

4<

CHAPTER I. INTRODUCTION

This document is intended to provide information pursuant to Section 304(d)(2) of the Federal Water Pollution Control Act Amendments of 1972 (the Act) on practicable techniques by which publicly-owned treatment works can restore and maintain the integrity of the Nation's waters. The document identifies the currently known techniques, summarizes the technology and includes an extensive bibliography (Appendix A).

A. STATUTORY REQUIREMENTS

The Act (P.L. 92-500) refers to best practicable waste treatment technology (BPWTT), or to the manner in which it is to be determined, in three key sections.

Under Section 304(d)(2), which imposes the earliest deadline ("within nine months of the enactment of this title, and from time to time thereafter"), EPA is to publish:

> "Information on alternative waste treatment management techniques and systems available to implement Section 201 of this Act".

Section 201, the only section where the phrase "best practicable waste treatment technology" actually appears, declares that:

> "Waste treatment management plans and practices shall provide for the application of the best practicable waste treatment technology before any discharge into receiving waters, including reclaiming and recycling of water, and confined disposal of pollutants so they will not migrate to cause water or other environmental pollution and shall provide for consideration of advance waste treatment techniques".

To realize this purpose, Section 201(g)(2)(A) stipulates that:

> "The Administrator shall not make grants from funds authorized for any fiscal year beginning after June 30, 1974, . . . unless . . . alternative waste management techniques have been studied and evaluated and the works proposed for grant assistance will provide for the application of the best practicable waste treatment technology over the life of the works consistent with the purposes of this title".

Funds for FY 1975, the first year affected by the BPWTT requirement, become available January 1, 1974.

Under Section 301(b)(2)(B) the requirements which pertain to publicly owned treatment works (POTW's) receiving Federal funds are generalized to all POTW's for 1983:

> "In order to carry out the objective of this Act [to restore and maintain the chemical, physical, and biological integrity of the Nation's waters] there shall be achieved . . . not later than July 1, 1983, compliance by all publicly owned treatment works with the requirements set forth in Section 201(g)(2)(A) of this Act".

In summary, the information developed under Section 304, which is first used for funding purposes under Section 201, is eventually used for enforcement purposes under Section 301. This is accomplished through National Pollutant Discharge Elimination System (NPDES) permits issued under Section 402, which allow the discharge of pollutants provided the discharge meets all applicable requirements of the Act (in this case, of Section 301).

B. LEGISLATIVE HISTORY

The earliest guidance on Sections 201, 301, or 304 is contained in the Senate Committee Report's comments on Section 201. There is a strong emphasis on land disposal, reflecting the original version of the legislation. It required land treatment as BPWTT except where a municipality

6<

could prove the superiority of another technique. In a different vein, the Committee also warned against reliance on conventional dry-weather waste treatment technology. The Committee noted that in many places water quality objectives will remain beyond reach until attention is given to the treatment of storm water runoff and combined sewer overflows.

The House Committee Report on Section 201 is in many respects a rejoinder to the Senate report. The House Committee warned against reliance on any one treatment technique as a panacea. Rather, it listed three standard alternative techniques for consideration: treatment and discharge to receiving water, treatment and reuse, and spray-irrigation or other land disposal methods. In its comments on Section 304, however, the House Committee did urge that the information EPA publishes on alternative waste management techniques emphasize land disposal. Finally, under Section 201, the House stressed that any determination of BPWTT should consider possible trade-offs between air, land and water disposal of pollutants.

C. SUMMARY OF CONCLUSIONS

Throughout the development of the Act, Congress emphasized that wastewater management systems other than treatment and discharge be evaluated in determining which alternative constitutes the best practicable waste treatment technology. Accordingly, a substantial portion of this document contains information on land application and treatment and reuse techniques.

The choice of which alternative to adopt is left to each municipality or regional sanitary district. If it receives Federal funds, however, it must be guided by the Agency's cost-effectiveness regulations (40 CFR Part 35, Appendix B).

Once one alternative is selected, it must comply with certain additional requirements, described in this document. For example, any land application or land utilization techniques must, in order to qualify for Federal funding, comply with criteria designed to protect ground waters. These criteria are intended to ensure that the nation's ground water -- resources remain suitable for drinking water purposes. The ground waters in the zone of saturation in any aquifer resulting from land or subsurface disposal must meet the chemical and pesticide levels in the EPA public drinking water criteria "Manual for Evaluating Public Drinking Water".

However, if the ground water presently exceeds the specified quality, case by case exceptions may be allowed provided no further degradation ensues. If the land application technique results in a point source discharge to navigable waters -- for example, one which utilizes an underdrain system -- that discharge must comply with applicable effluent limitations for discharges from publicly owned treatment works.

The general criteria for reuse may vary greatly depending on the intended use of the effluent and the consequent quality of water required. Restrictions on reuse have been kept to a minimum in order to encourage reuse of wastewaters. At the same time, reuse should not be allowed to result in greater pollution of either ground or surface waters than the other two major alternatives of land disposal and classical treatment and discharge. Accordingly, in order to qualify for Federal grant support under the Act, any reuse system must conform to the criteria for ground water protection described above, and to the requirements applicable to direct discharge of pollutants by publicly owned treatment works.

Finally, this document describes several waste management techniques involving treatment and discharge, including flow reduction and storm and combined sewer control. The selection of any particular treatment management technique should be governed by cost-effectiveness as well as by general environmental considerations. The requirement that any treatment works achieve the effluent reductions associated with secondary treatment (40 CFR Part 133) Appendix B continues in force as a minimum prerequisite for eligibility for Federal funding. Requirements for additional treatment, or alternative management techniques, will depend upon several factors, including availability of technology, cost and the specific characteristics of the affected receiving water body. As the report indicates, protection of dissolved oxygen levels will most frequently have the highest priority once secondary treatment levels have been attained and may, in many cases, be required in order to meet water quality standards. The report contains information on the use of the parameter ultimate oxygen demand (UOD) in place of the BOD_5 parameter in which secondary treatment reduction levels are expressed. Since UOD measures not only the oxygen demand of carbonaceous organic material in waste effluent but that of nitrogenous material as well, in areas in which low dissolved oxygen presents a significant problem, use of this parameter and extension of treatment to include seasonal nitrification may well constitute best practicable treatment. Less frequently, nutrient removal may be warranted. The report describes the efficiencies of various treatment methods in removal of the principal nutrients: carbon; nitrogen and phosphorus.

CHAPTER II. WASTE MANAGEMENT TECHNIQUES INVOLVING LAND APPLICATION OR LAND UTILIZATION

Land application and land utilization are the two major wastewater management techniques that do not result in point-source discharges. Achieving best practicable technology by either method involves meeting the ground water criteria.

Land application techniques are of two types with respect to discharge. One type involves collection of wastewater in underdrain systems; where these systems discharge to navigable waters, they must meet the treatment and discharge criteria. The other type of land application technique involves the percolation of wastewater through the soil until it becomes part of the permanent aquifer. This does not constitute a point-source discharge into navigable waters.

The ground water criteria reflect the resolution of several questions. The first question is the level of ground water protection desired. Here, the criteria are keyed to the somewhat conflicting goals of making land application technologically and economically feasible while protecting the ground water from permanent contamination or costly renovation. Analysis of the kinds of ground water pollution that can exist suggests the cut-off point.

The types of pollutants affecting ground water fall into three broad categories: Chemical pollutants such as heavy metals, dissolved salts, and nitrates; organic pollutants such as pesticides and residual organics; and pathogenic pollutants such as bacteria. The technology for removing heavy metals, dissolved salts, and nitrates in a treatment plant to levels that will meet drinking water standards is not practicable for publicly-owned plants. The technology exists to remove pesticides and residual organic compounds from ground water. Activated carbon adsorption can be used in a water treatment plant to reduce organic pollutants to levels acceptable for drinking water purposes. However, the estimated total amortized cost is from 10 to 20 cents per 100 gallons,

1U<

which can be more than double the normal cost of water treatment. The standard water treatment facility is designed to reduce pathogenic pollution to levels acceptable for drinking water and therefore no criteria are needed. The criteria for the best practicable treatment in a land application system do, however, require reducing chemical and organic pollutants to raw or untreated drinking water supply source levels. This requirement would apply to processing of both effluent and sludge.

Another question in land application is the determination of the point of distinction between process effluent and ambient (ground water) conditions. The gradations of percent saturation of the soil are infinite, and cost of land application will vary according to where the effluent-ambient line is drawn. The recommended point of distinction is the point of ground water saturation, the highest point where a well could draw out ground water. This makes better sense environmentally and is more easily administered than setting the effluent-ambient point at a fixed depth below ground level or calculating it by a formula dependent upon soil type and/or climate. Another place of measurement, which is easier to enforce, could be imposed at the point of application prior to land application. Because this concept would not measure the effect of land application, it is not recommended.

For the purposes of establishing eligibility for grant funding under Title II of the Act, the discharge of pollutants onto the land should not degrade the air, land, or navigable or ground waters; should not interfere with the attainment or maintenance of public health State or local land use policies; and should insure the protection of public water supplies, agricultural and industrial water uses, propagation of a balance population of aquatic and land flora and fauna, and recreational activities in the area. Land application systems shall be so designed that the permanent ground waters (ground water which is not removed from the ground by an underdrain system or other mechanical means) which are in the zone of saturation (where the water is not held in the ground by capillary tension) that result from the application of wastewater will not exceed the chemical or pesticides

11<

levels for raw or untreated drinking water supply sources in the EPA Manual for Evaluating Public Drinking Water Supplies as specified below:

(1) Chemical Quality:

	Units of Measurements	Maximum Allowable Limits
Arsenic	mg/l	0.1
Barium	mg/l	1
Chloride	mg/l	250
Chromium	mg/l	0.05
Copper	mg/l	1
Fluoride	mg/l	1.1
Foaming Agents as Methylene Blue Active Substances	mg/l	0.5
Iron	mg/l	0.3
Lead	mg/l	0.05
Manganese	mg/l	0.05
Nitrate Nitrogen	mg/l	10
Carbon Absorbable Organics-Carbon; Chloroform Extractable (CCE)	mg/l	0.3
Carbon Absorbable Organics-Carbon; Alcohol Extractable (CAE)	mg/l	1.5
Selenium	mg/l	0.01
Silver	mg/l	0.05
Sodium	mg/l	270
Sulfate	mg/l	250
Zinc	mg/l	5

(2) Pesticides;

	Units of Measurements	Maximum Permissible Concentration
Chlordane	mg/l	0.01
Heptachlor	mg/l	0.02
Heptachlor epoxide	mg/l	0.02
Heptachlor and Heptachlor epoxide	mg/l	0.02
Lindane	mg/l	0.1
Methoxychlor	mg/l	0.5
2,4-D	mg/l	1
2,4,5-T	mg/l	0.005
2,4,5-TP	mg/l	0.02

Effluent standards for the following toxic pollutants have been proposed pursuant to § 307(a) of the Act. These proposed standards are being considered at public hearings, and will be promulgated at the conclusion of the hearings. Any effluent standards promulgated for these pollutants under § 307(a) will be taken into account when the standards proposed herein are promulgated or revised:

Cadmium
Cyanide
Mercury
Aldrin and Dieldrin
DDT
Endrin
Toxaphene

Any public drinking water standards hereafter issued by EPA which prescribe maximum allowable limits or permissible concentrations of chemicals or pesticides shall apply in lieu of those listed above.

If the presently existing concentration of any parameter is higher in the ground water than the levels specified above then the use of a land disposal technique should not result in an increase in the concentration of that parameter.

13<

---

[a] Expressed in terms of parathion equivalent cholinesterase inhibition.

A. LAND APPLICATION TECHNIQUES

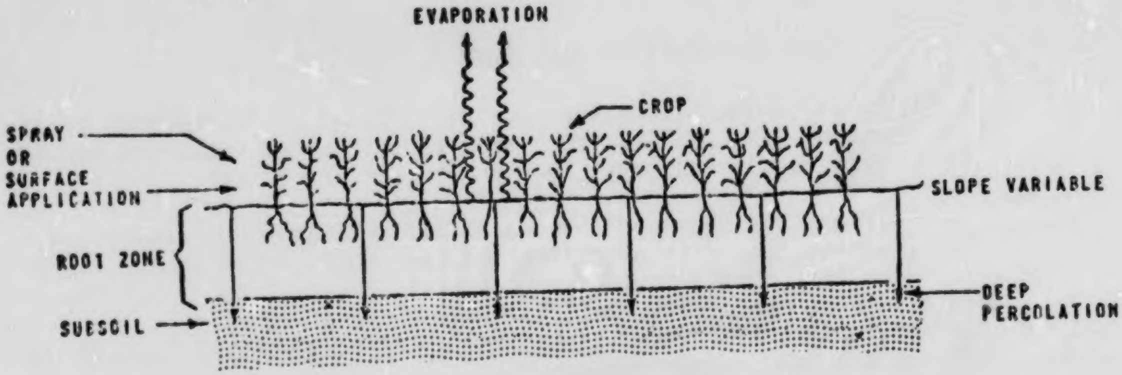
The following discussion is largely based on "Wastewater Treatment and Reuse by Land Application," written by Charles Pound and Ronald Crites of Metcalf and Eddy, Inc. under contract to EPA.

Irrigation, overland flow, and infiltration-percolation, the three basic approaches to land application, are shown schematically in Figure 1. Their major characteristics are listed in Tables 1 and 2 and Figure 2. In all three approaches, wastewater may be applied by spraying or other surface application techniques. These other approaches include leaching fields and evaporation ponds.

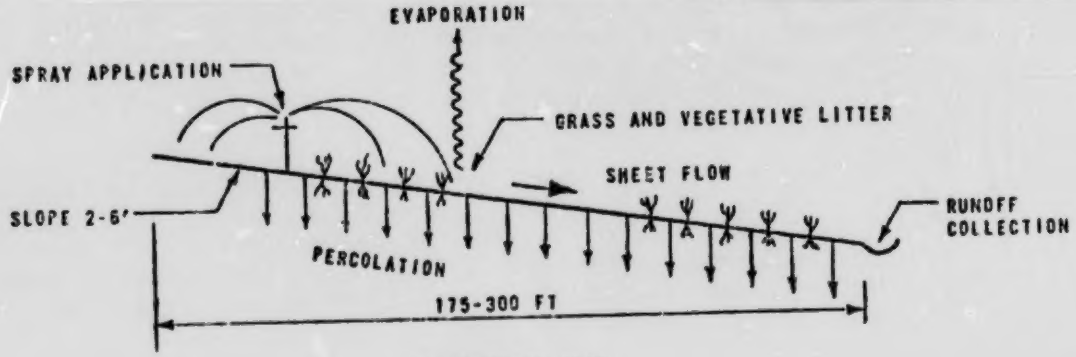
Municipal wastewater, usually pretreated to some extent, has been applied to land mainly by irrigation and infiltration. Recently, municipal installations have begun to experiment with overland flow. Industrial wastewater, generally screened or settled, has been applied using all three approaches, with the choice usually depending on the type of soil nearby.

Irrigation. Irrigation is the most widely used type of land application. Between 100 and 450 U. S. communities practice this approach. The controlling factors in this type of land application are site selection and design, methods of irrigation, loading rates, management and cropping practices, and the expected treatment or removal of wastewater constituents.

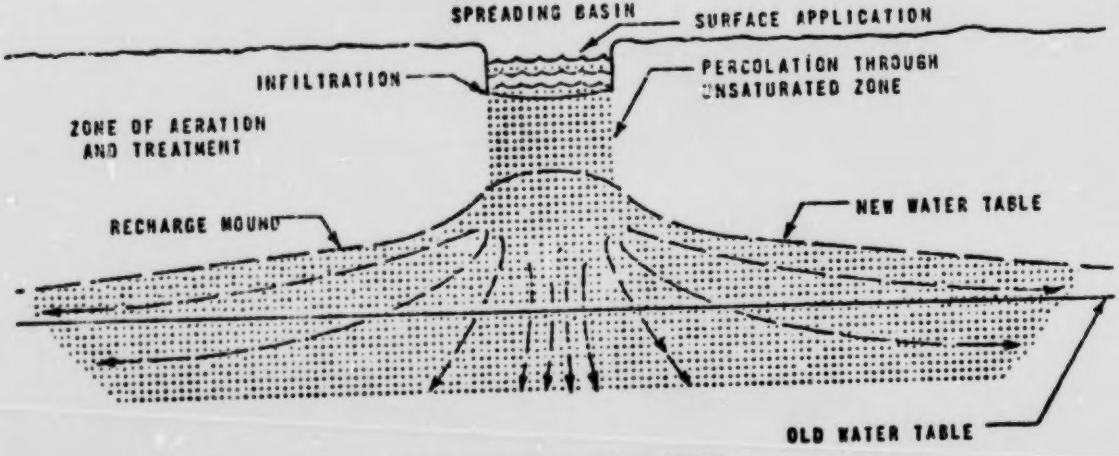
The major factors involved in site selection are: type, drainability, and depth of soil; nature, variation of depth, quality, and present and potential use of ground water; location, depth, and type of underground formation; topography, and considerations of public access to the land. Climate is as important as the land in the design and operation of irrigation systems. It is not a variable, however, because feasible sites must be within economic transmission distance of the source.


EVAPORATION
CROP
SPRAY
OR
SURFACE
APPLICATION
SLOPE VARIABLE
ROOT ZONE
DEEP
PERCOLATION
SUBSOIL

a) IRRIGATION


EVAPORATION
SPRAY APPLICATION
GRASS AND VEGETATIVE LITTER
SHEET FLOW
SLOPE 2-6%
RUNOFF
COLLECTION
PERCOLATION
175-300 FT

b) OVERLAND FLOW


SPREADING BASIN
SURFACE APPLICATION
INFILTRATION
PERCOLATION THROUGH
UNSATURATED ZONE
ZONE OF AERATION
AND TREATMENT
RECHARGE MOUND
NEW WATER TABLE
OLD WATER TABLE

c) INFILTRATION-PERCOLATION

Figure 1. Land Application Approaches

15<

Table 1. Comparative Characteristics of Land-Application Approaches

Factor	Type of Approach		
	Irrigation	Overland flow	Infiltration-percolation
Liquid-loading rate	0.5 to 4 in/wk	2 to 5.5 in/wk	0.3 to 1.0 ft/wk
Annual application	2 to 8 ft/yr	8 to 24 ft/yr	18 to 500 ft/yr
Land required for 1-MGD flow	62 to 560 acres plus buffer zones	46 to 140 acres plus buffer zones	2 to 62 acres plus buffer zones
Application techniques	Spray or surface	Usually spray	Usually surface
Soils	Moderately permeable soils with good productivity when irrigated	Slowly permeable soils such as clay loams and clay	Rapidly permeable soils such as sands, loamy sands, and sandy loams
Probability of influencing groundwater quality	Moderate	Slight	Certain
Needed depth to groundwater	About 5 ft	Undetermined	About 15 ft
Wastewater losses:	Predominantly evaporation or deep percolation	Predominantly surface discharge but some evaporation and percolation	Percolation to groundwater

17<

Table 2. Comparison of Potential Objectives for Land-Application Approaches

Objective	Type of approach		
	Irrigation	Overland flow	Infiltration-percolation
Use as a treatment process with a recovery of treated water	Impractical	50 to 60% recovery	Up to 90% recovery
Use for treatment beyond secondary:			
1. For BOD and suspended solids removal	90-99%	90-99%	90-99%
2. For nitrogen removal	85-90%	70-90%	0-80%
3. For phosphorus removal	80-99%	50-60%	70-95%
Use to grow crops for sale	Excellent	Fair	Poor
Use as direct recycle to the land	Complete	Partial	Complete
Use to recharge groundwater	0-30%	0-10%	Up to 90%
Use in cold climates	Fair[a]	--[b]	Excellent

a. Conflicting data -- woods irrigation acceptable, cropland irrigation marginal.

b. Insufficient data.

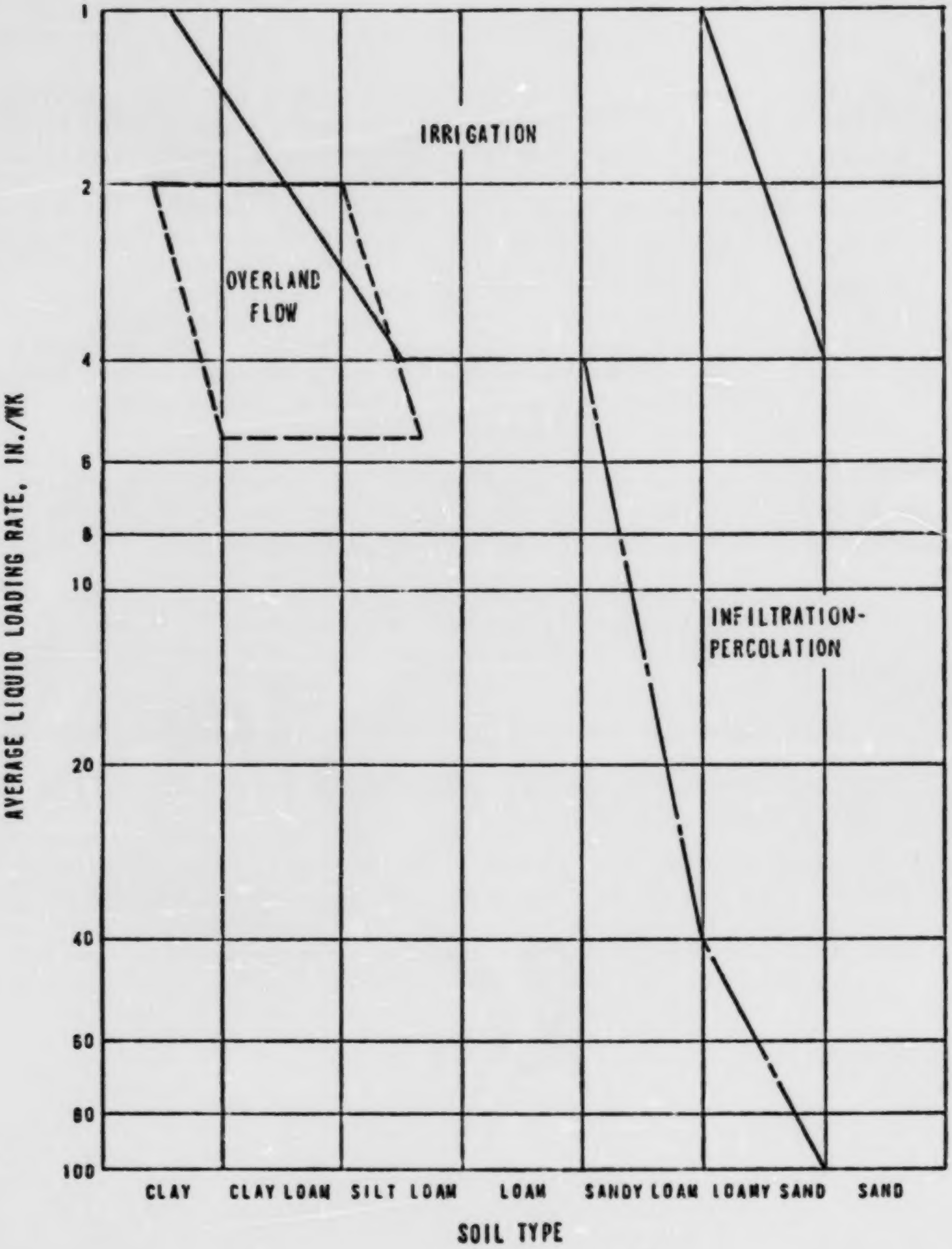


Figure 2. Soil Type Versus Liquid-Loading Rates for Different Land-Application Approaches

The major factors and generalized criteria for site selection are listed in Table 3. Soil drainability is perhaps the primary factor, and agricultural extension service advisers or adjacent farmers should be consulted about drainability of cropland. For forest or landscape irrigation, university specialists should be consulted. The drainability is important because, coupled with the type of crop or vegetation selected, it directly affects the liquid loading rate. The ideal is a moderately permeable soil capable of infiltrating approximately 2 inches per day or more on an intermittent basis. In general, soils ranging from clay loams to sandy loams are suitable for irrigation. Soil depth should be at least 2 feet of homogenous material and preferably 5 to 6 feet throughout the site. This depth is needed for extensive root development of some plants, as well as for wastewater treatment.

The minimum depth to ground water should be 5 feet to ensure aerobic conditions. If the native ground water is within 10 to 20 feet of the surface, control procedures such as underdrains or wells may be required.

For crop irrigation, slopes are generally limited to about 10 percent or less, depending upon the type of farm equipment to be used. Heavily foliated hillsides up to 30 percent in slope have been spray-irrigated successfully.

A suitable site for wastewater irrigation would preferably be located in an area where contact between the public and the irrigation water and land is limited. However, this is often impossible in landscape irrigation.

Three basic methods of irrigating are spray, ridge and furrow, and flood. Spray irrigation may be accomplished using a variety of systems from portable to solid-set sprinklers. Ridge and furrow irrigation consists of applying water by gravity flow into furrows; relatively flat land is groomed into alternating ridges and furrows, with crops grown on the ridges. Flood irrigation is the inundation of land with several inches of water. The type of irrigation system used depends on soil drainability, crop, topography, and economics.

Table 3. Site Selection Factors and Criteria for Irrigation

Factor	Criterion
Soil type	Loamy soils preferable, but most soils from sands to clays are acceptable
Soil drainability	Well-drained (more than 2 in./day) soil preferred; consult experienced agricultural advisers
Soil depth	Uniformly at least 5 to 6 ft throughout site
Depth to groundwater	Minimum of 5 ft
Groundwater control	May be necessary to ensure treatment if water table is less than 10 ft from surface
Groundwater movement	Velocity and direction must be determined
Slopes	Up to 15% are acceptable with or without terracing
Underground formations	Should be mapped and analyzed with respect to interference with groundwater or percolating water movement
Isolation	Moderate isolation from public preferable, the degree depending on wastewater characteristics, method of application, and crop
Distance from source of wastewater	Economics

The important loading rates are liquid loading in terms of inches per week, and nitrogen loading in terms of pounds per acre per year. Organic loading rates are less important if an intermittent application schedule is followed. Liquid loadings may range from 0.5 to 4.2 inches per week depending on soil, crop, climate, and wastewater characteristics. Crop requirements generally range from 0.2 to 2.0 inches per week, although a specific crop's water needs will vary throughout the growing season. Typical liquid loadings are from 1.5 to 4.0 inches per week. Although wastewater irrigation rates have ranged up to 7 or 8 inches per week, a generalized division between irrigation and infiltration-percolation systems is 4 inches per week.

Nitrogen-loading rates have been calculated because of nitrate buildup in soils, underdrain waters, and ground waters. To minimize such buildup, the weight of total nitrogen applied in a year should not greatly exceed the weight removed by crop harvest. With loamy soils, the permissible liquid-loading rate will be the controlling factor in most cases; for more porous, sandy soils the nitrogen-loading rate may be the controlling factor.

Crop selection can be based on several factors: high water and nutrient uptake, salt or boron tolerance, market value, or management requirements. Popular crop choices are grasses with high year-round uptakes of water and nitrogen and low maintenance requirements. A drying period ranging from several hours each day to several weeks is required to maintain aerobic soil conditions. The length of time depends upon the crop, the wastewater characteristics, and the length of the application period. A ratio of drying to wetting of about 3 or 4 to 1 should be considered a minimum.

Treatment of the wastewater often occurs after passage through the first 2 to 4 feet of soil. The extent of treatment is generally not monitored; when it is, however, removals are found to be on the order of 99 percent for BOD, suspended solids, and bacteria. As irrigation soils are loamy with considerable organic matter, the heavy metals, phosphorus, and viruses have been found to be nearly completely removed by adsorption. Nitrogen is taken up by plant growth; if the crop is harvested, the removals can be on the order of 90 percent.

21

Wastewater irrigation has been shown to have a long useful life. Examples are the systems at Cheyenne, Wyo., operating since 1881; at Fresno, Calif., operating since 1891; and at Bakersfield, Calif., operating since 1912.

Wastewater treatment is quite effective at direct recycling of pollutants to the land. Even if an irrigation operation is poorly managed, the adverse environmental effects are slight. Irrigation has had many positive effects on the environment, such as providing wildlife habitats. In general, irrigation is considered the most reliable approach to land application of wastewater.

Capital costs for irrigation include those for land, pretreatment, transmission, and distribution. Operating and maintenance costs are for labor, maintenance, and power. The direct economic benefits from irrigation can offset some of the operating costs.

Land costs vary tremendously, but a typical current price is $500 per acre. Pretreatment costs for a 1-million-gallon-per-day (MGD) system range from 2.7 cents per 1,000 gallons for screening to 34.6 cents per 1,000 gallons for activated sludge. These costs are totals determined by adding amortized capital costs (25 years at 7 percent) to operating and maintenance costs. The figures are updated to January 1973.

Capital costs for spray irrigation for 10 Michigan sites in 1972 ranged from $1,000 to $5,000 per acre. Costs reported for cannery waste-disposal systems (in 1971) varied from $200 to $2,300 per acre. A cost (in 1967) for a 1-MGD system on 129 acres of $2,700 per acre was also reported; the amortized cost (20 years at 6 percent) was 10 cents per 1,000 gallons of wastewater treated.

For spray sites the reported costs were: $800 per acre (in 1968) for the solid set system at Idaho Supreme; $1,500 per acre (in 1966) for golf course irrigation at Moulton-Niguel in Southern California; and $140 per acre (in 1968) for a center pivot rig at Portales, N.M.

Reported operating and maintenance costs, including pretreatment, for six municipal systems varied from 2.7 to 11.6 cents per 1,000 gallons. The costs for six industrial-wastewater systems ranged from 7.3 to 23.9 cents per 1,000 gallons in 1972. The higher operating costs were for canneries operating on a seasonal basis. Estimated cost for spraying hardboard wastes is 5 cents per 1,000 gallons.

At the Mount Vernon Sanitary District in California, costs for a 1,000-acre ridge-and-furrow irrigation system (in 1956) were $75 per acre, including leveling, preparation, and fertilizing. Other plants reported ridge and furrow capital costs of $300 per acre for a Minnesota creamery (in 1950) and $2,000 per acre for a Wisconsin creamery (in 1954).

Operating and maintenance costs at Beardmore, Canada (in 1958) were 12.7 cents per 1,000 gallons. Costs at the Green Giant Co. cannery in Montgomery, Minn. (in 1953) were 22.2 cents per 1,000 gallons.

Provided that the land is relatively level, capital costs for flood irrigation will be less than for spray or ridge and furrow. Capital costs however, were not reported in the literature. Operating and maintenance costs for flooding at Abilene, Tex., were 7 cents per 1,000 gallons and at Woodland, Calif., 4.2 cents. Both costs include pretreatment.

Cities using irrigation derive direct benefits in different ways. At Woodland, Calif., the city's land is leased for $23 per acre per year for summer irrigation; in addition, a duck club pays about $6 per acre per year for the same land for duck-hunting privileges in late fall. At Abilene, Tex., city land is leased for $12 per acre per year, and additional effluent is provided to adjacent farms. Pomona purchases treated wastewater from the Los Angeles County Sanitation Districts at $7 per acre-foot and sells it to various users at $5 to $22 per acre-foot. San Angelo, Tex. operates a 750-acre city farm at an annual profit of $30 per acre.

Overland Flow. In overland flow the land is sloping, the water runs off, and the crop is not always harvested.

23

Overland flow has been used for some time. The method has been tried experimentally on municipal wastewater at Ada, Okla., but it has been more completely developed for use in the United States on food-processing wastewater. The important factors in overland flow are site selection, design loadings, management practices, and treatment to be expected. If the runoff water is collected and discharged into a navigable water, it will have to meet the treatment and discharge criteria.

Soils suited to overland flow are clays and clay loams with limited drainability. The land should have a slope of between 2 and 6 percent, so that the wastewater will flow in a sheet over the ground surface. Grass is planted to provide a habitat for the bacteria which help purify the wastewater. As runoff is expected, suitable surface waters should be nearby to receive the discharge.

Because ground water will not likely be affected by overland flow, it is of minor concern in site selection. The ground water table should be deeper than 2 feet, however, so that the root zone is not waterlogged.

Even though climatic constraints have not been thoroughly tested, systems are being operated in California, Texas, Ohio, Pennsylvania, Indiana, and Maryland. A system designed at Glenn, Mich., in 1972 will attempt to use overland flow when the ground is frozen. At Melbourne overland flow is used only during the mild winters when evaporation is low.

Overland flow systems are generally designed on the basis of liquid-loading rates, although an organic-loading or detention-time criterion might be developed in the future. The process is essentially biological, with a minimum contact time between bacteria and wastewater required for adequate treatment. Liquid-loading rates used in design have ranged from 2.5 to 5.5 inches per week, with a typical loading being 4 inches per week. At Ada the optimum loading has been around 4 inches per week, while at Melbourne it is 5.2 inches per week.

Management practices important in overland flow are maintaining the proper hydraulic loading cycle (periods of application followed by resting), maintaining an active biota and a growing grass, and monitoring the performance of the system. Hydraulic loading cycles have been found to range from 6 to 8 hours of spraying followed by 6 to 18 hours of drying. Periodic cutting of the grass with or without removal is important, but the effects on organic oxidation have not been fully demonstrated. Loading cycles must be monitored for maximum removal efficiencies.

Treatment of wastewater by overland flow is only slightly less complete than that for irrigation. The overland flow systems at Melbourne and Ada (both using municipal wastewater) and at Paris, Tex. (using industrial wastewater), have been monitored to determine removal efficiencies. The results suggest BOD and suspended solids removals of 95 to 99 percent, nitogen removals of 70 to 90 percent, and phosphorus removals of 50 to 60 percent. Solids and organics are removed by biological oxidation of the solids as they pass through the vegetative litter. Nutrients are removed mainly by crop uptake. Other removal mechanisms for nutrients include biological uptake, denitrification, and fixation in the soil.

Less is known about the useful life of an overland flow system than an irrigation system. The Melbourne system has been operating successfully for many years as a wintertime alternative to irrigation. The oldest operating system in this country, however, has been treating industrial wastewater for less than 20 years. Analysis of the literature suggests that an indefinite useful life may be possible if effective management continues.

Adverse environmental effects should be minimal. As a runoff flow is created, it must be stored, reused, or discharged to a surface watercourse. As infiltration into the soil is slight, the chances of affecting ground water quality are low.

Cost data on overland flow facilities are scarce because of the limited number of overland flow sites in operation. Capital costs include land, pretreatment, transmission, earthwork, distribution, and collection. Land costs are quite variable; even at the Paris site, they varied from $50 to $600 per acre for the 500 acres purchased. Pretreatment generally consists of screening. Transmission generally is by pumping.

25<

Earthwork will vary with the original topography of the site. At Paris, the rolling land was regraded at a cost of $306 per acre for clearing, $108 per acre for grass cover, and $188 per acre for miscellaneous work. On the other hand, complete regrading of flat land to 2.5 percent slopes at the Hunt-Wesson Co. site in Davis, Calif. cost $1,500 per acre.

The original distribution system for Paris cost $348 per acre to install. The cost (in 1971) for the piping at the Davis site was about $1,250 per acre. Collection systems for the runoff are normally included under earthwork. At Davis the collection ditches amounted to 10 percent of the earthwork cost, or about $150 per acre.

At Paris, the annual operational cost is 5 cents per 1,000 gallons. The operational cost is reduced slightly by the income of 0.4 cent per 1,000 gallons from crops produced on the site. At Davis the annual cost is 5 to 10 cents per 1,000 gallons.

Infiltration-Percolation. Infiltration-percolation has been used with moderate loading rates (4 to 12 inches per week) as an alternative to discharging effluent to surface waters. High-rate systems (5 to 8 feet per week) have been designed to recharge ground water. As they have been carefully designed and monitored, they will be stressed in the following discussion.

Soil drainability on the order of 4 to 12 inches per day or more is necessary for successful use of infiltration-percolation. Acceptable soil types include sand, sandy loams, loamy sands, and gravels. Very coarse sand and gravel are less desirable, because they allow wastewater to pass too rapidly through the first few feet, where the major biological and chemical action takes place.

Other factors of importance include deep percolation rates; depth, movement, and quality of ground water; topography; and underlying geologic formations. To control the wastewater after it infiltrates the surface and percolates through the soil matrix, the subsoil and aquifer characteristics must be known. Recharge should not be attempted without specific knowledge of the movement of the water in the soil system.

Organic-loading rates of municipal systems range from 3 to 15 tons of BOD per acre per year. Industrial systems have operated successfully at 90 tons. Municipal systems generally pretreat the wastewater to secondary quality to maintain high liquid-loading rates. Industries have tended to rely more on the assimilative capacity of the soil, generally using pretreatment only to avoid operational problems.

Management practices important to infiltration-percolation systems include maintenance of hydraulic loading cycles, basin surface management, and system monitoring. Intermittent application of wastewater is required to maintain high infiltration rates, and the optimum cycle between inundation periods and resting periods must be determined for each individual case. Basin surfaces may be bare or covered with gravel or vegetation. Each type of surface requires some maintenance and inspection for a satisfactory operation. Monitoring, especially of ground water levels and quality, is essential to system management.

The filtering and straining action of the soil are excellent, so suspended solids, bacteria, and BOD are almost completely removed in most cases. Nitrogen removals are generally poor unless specific operating procedures are established to maximize denitrification. Phosphorus removals range from 70 to 90 percent, depending on the percentage of clay or organic matter in the soil matrix which will adsorb phosphate ions.

Wastewater treatment by infiltration-percolation varies considerably with soil characteristics and management practices. By careful management of the hydraulic loading cycle (2 to 3 weeks of wetting, 2 weeks of drying), Flushing Meadows, Ariz. has obtained nitrogen removals up to 80 percent. Overall nitrogen removal, taking into account the high nitrate concentration flushed to the ground water at the beginning of inundation, averaged 30 percent. Removals of phosphorus and heavy metals were also generally less than for irrigation.

The useful life of an infiltration-percolation system will be shorter, in most cases, than that for irrigation or overland flow. This is caused by higher loadings of inorganic constituents, such as phosphorus and heavy metals, and by the fact that these constituents are fixed in the soil matrix and not positively removed. Therefore, exhaustion of the fixation capacity for phosphorus and heavy metals will be a function of the loading rate and the fixation sites available. At Lake George, New York, phosphorus retention on the basis of recent monitoring in some percolation beds appears to have been exhausted. The system had been operating about 35 years at moderate rates of 7 to 15 inches/week.

From the standpoint of environmental effects, infiltration-percolation is the least reliable of the three approaches relative to the best practicable criteria. Most systems that have been monitored and managed properly, however, proved to be quite reliable.

Capital and operating costs for infiltration-percolation systems will generally be less than those for irrigation or overland flow, because less land is used and distribution is by gravity flow. For high-rate systems, however, pretreatment needs are substantially greater.

The capital costs for infiltration-percolation are for land, pretreatment, earthwork, transmission and distribution, and recovery. At Westby, Wis., basins were constructed in a 5 percent hillside. The land cost was $750 per acre; earthwork was $2,500 per acre. The earthwork cost at Flushing Meadows was $4,500 per acre. Others have calculated the cost of transmission and distribution at Flushing Meadows at $98,000. The recovery wells there cost $35 per foot, or $17,500 for each well.

Operation and maintenance costs for infiltration-percolation systems consist of costs for labor, maintenance, and power. At Flushing Meadows, the operating cost is 2.4 cents per 1,000 gallons, while at Whittier Narrows, Calif., it is 2.7 cents.

Simpson Lee Paper Co. operates two pulp and paper waste-disposal systems by infiltration-percolation. At Kalamazoo, Mich., 7 inches per day is applied by spraying and at Vicksburg, Mich., 1 inch per day is applied by spraying. The operating cost is 2.6 cents per 1,000 gallons at Kalamazoo, and 2.9 cents at Vicksburg. Pretreatment costs for primary settling are included in both costs.

Other Land Application Techniques. There are several other approaches to land application, including subsurface leach fields, deep-well injection, and evaporation ponds. Such techniques are generally limited in their applicability. Leach fields are prevalent in rural areas for small systems involving septic tanks and are unlikely to become more widespread. Deepwell injection provides no substantial renovation to the wastewater and is not allowed by the best-practicable-treatment criteria unless pretreatment is of a high-enough quality. Evaporation ponds also have limited applicability because of their large land requirements and climatic constraints, but some are in use.

B. LAND UTILIZATION TECHNIQUES

Wastes and sludges from wastewater treatment plants are often ultimately disposed of on the land by such processes as surface spreading or landfill disposal of dewatered and stabilized sludge, landfill disposal of incineration ash, and composting.

Land Spreading of Sludge. Land spreading of either chemically- or biologically-stabilized sludge is generally similar to the land application of wastewater. Occasionally, land spreading is limited by the ability of the land to accept the large amounts of water in the sludge. More often it is limited by the ability of the land to accept high concentrations of salts, organic matter, heavy metals, and pathogenic organisms.

Sludge can be applied by spray or ridge and furrow irrigation. Procedures used in land application techniques are followed for site selection and cropping. Likewise, the amount of nitrogen compound, nitrates and ammonia, is expected to be limiting. Ammonia may have to be removed by denitrification prior to application. Ammonia may interfere with seed germination and nitrates may reach the ground water.

In Great Britain 20 to 30 communities practice land spreading. The solids content of the stabilized sludge varies between 2 and 5 percent. The application of less than 5 tons of dry solids per acre per year has been successful. Monitoring of heavy metals has not revealed problems at this level of application.

The Chicago Metropolitan Sanitary District is now spraying sludge on 7,000 acres. The land is prepared by leveling to less than 5 percent grade and building earth berms to control runoff. Application rates of 2 inches of sludge per year are expected to be successful. At higher rates, nitrogen compounds would have to be removed. Aeration techniques have been studied and should be successful in oxidizing ammonia nitrogen.

Another method of land spreading involves application of dried sludge, which contains less nutrient, namely nitrogen, in the liquid streams. When the dry sludge is packaged, as it is in Milwaukee, Wis., it can be sold as a soil conditioner. This conserves space in land disposal sites.

Landfill of Sludge. Stabilized sludge, dewatered to approximately 30 percent solids, can be disposed of by sanitary landfill, the controlled burial of waste beneath an earth cover. Another method of landfill is dumping. The U.S. Department of Agriculture is experimenting with a variety of sludges, successfully burying the sludges in 2-foot-wide, 2- to 4-foot deep trenches with a 1-foot soil cover. Other methods such as deep disking and rotary tilling will also be tested.

Dumping of dewatered sludge without cover requires great care to prevent damage to the environment. Sufficient land must be available, runoff and percolation of the leachate to the ground water must be controlled and monitored, and odors and pathogenic problems must be dealt with. When properly managed, dumps generally compare in operational cost to sanitary landfill. Landfill is much more sound environmentally, and is the preferred method of disposal.

Landfill of Incinerator Ash. Where land is scare or distant, incineration is often an economically attractive method for disposing of treatment-plant sludge. The ash from incinerated municipal sludges is only 3 to 10 percent of the mass of dewatered sludge cake, and incineration reduces odors and pathogens.

30<

Composting and Final Disposal. Sewage sludge can be decomposed by composting, an aerobic digestion process that converts organic material into a soil conditioner. Moisture content of the sludge is reduced to approximately 50 percent. Biological action heats the sludge to an average temperature over 70°C. for an excess of 5 days. Nearly all pathogenic organisms are destroyed. The end product can be applied to the land or put into a sanitary landfill.

C. NONPOINT SOURCES OF POLLUTANTS

Information on nonpoint sources of pollutants, such as agricultural runoff from agricultural, construction, and mining activity is being published pursuant to Section 304(e) of the Act. However, the information and techniques discussed in that publication ought to be an integral part of the total area-wide waste management system. All techniques of water pollution abatement should be considered in area-wide programs to arrive at the best practicable treatment.

31<

CHAPTER III. WASTE MANAGEMENT TECHNIQUES INVOLVING TREATMENT AND DISCHARGE

Treatment and discharge is the technique used by the greatest number of publicly-owned treatment works (POTW's). There are an estimated 21,118 such works of different sizes in the United States employing different methods of treatment (Table 4).

The development of treatment and discharge technology follows a basic pattern (Figure 3): raw discharge, primary treatment, secondary treatment, advanced waste or tertiary treatment for nutrient removal, and renovation. The initial goal of the Act requires that POTW's utilizing treatment and discharge meet secondary treatment as defined by EPA by July 1, 1977 or June 1, 1978 (for new construction). The second goal of the Act is to provide application of best practicable treatment by July 1, 1983.

Table 4. Estimated Distribution of Publicly-Owned Treatment Works

	Major Plants (1 MGD or more)			Minor Plants (1 MGD or less)		Total
	WQL[a]	EL[b]	EL-OO[c]	WQL	EL	
None	29	32	3	944	1,462	2,467
Primary	549	366	62	828	1,278	3,022
Pond	87	50	7	1,800	2,791	4,728
Trickling Filter	574	382	57	1,367	2,015	4,338
Activated Sludge	235	219	35	872	1,162	2,488
Extended Aeration	42	29	4	686	1,071	1,828
Secondary - Other	112	77	13	518	879	1,586
Land Disposal	5	3	--	58	91	157
Tertiary	42	30	4	169	263	504
Total	1,676	1,188	185	7,242	11,012	21,118

a. Plants located on water-quality-limited segments.
b. Plants located on effluent-limited segments.
c. Plants located on effluent-limited segments with ocean outfalls.

32<

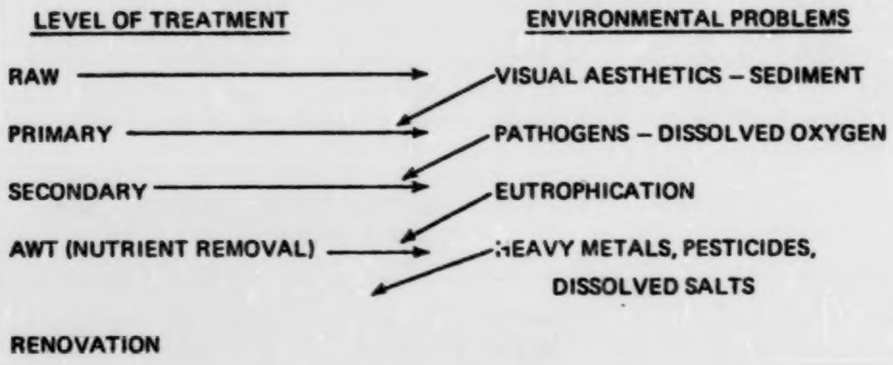

LEVEL OF TREATMENT
ENVIRONMENTAL PROBLEMS
RAW
VISUAL AESTHETICS – SEDIMENT
PRIMARY
PATHOGENS – DISSOLVED OXYGEN
SECONDARY
EUTROPHICATION
AWT (NUTRIENT REMOVAL)
HEAVY METALS, PESTICIDES, DISSOLVED SALTS
RENOVATION

Figure 3. Environmental Problems Associated With Treatment and Discharge

Criteria for best practicable treatment must be environmentally sound as well as technologically achievable. Three types of water quality problems are likely to remain after the application of the secondary treatment controls in 1977: oxygen-demanding material, nutrients which contribute to eutrophication (phosphorus and nitrogen), and fecal coliform. Review of the literature, and review of existing water quality surveys indicate that protection of the dissolved oxygen in receiving waters has the highest priority in the vast majority of cases. Approximately 50 percent of the Nation's POTW's discharge into receiving waters where the water quality problem is unsolved by existing regulations. In these water-quality-limited segments, almost all of the plants are expected to require an effluent containing less oxygen-demanding material than that achievable by secondary treatment.

Eutrophication typically occurs mainly in lakes and slow-moving estuaries. A recent study reveals that only 15 percent of the POTW's discharge to lakes, and half of these (or 7-12 percent of the total) require phosphorus control and one-third (or 5 percent) require nitrogen control.

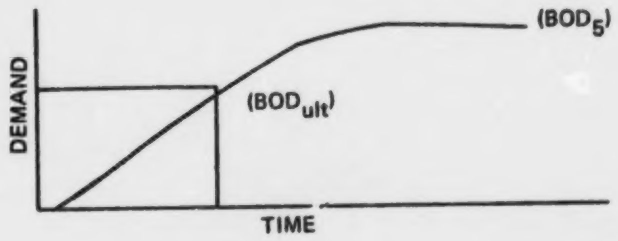
The fecal coliform standards as established by the secondary treatment criteria were set at levels which would ensure the highest recreational use (primary contact recreation).

The parameter used in secondary treatment to measure oxygen-demanding material in waste is 5-day biochemical oxygen demand (BOD_5). The BOD_5 test essentially measures the oxygen demand of only the carbonaceous organic material in the wastewater effluent. It does not measure the oxygen demand of the nitrogenous organic material, which exerts its effect in the test later than the carbonaceous material (Figure 4).

A parameter, ultimate oxygen demand (UOD), is a superior parameter for measuring the oxygen demand from municipal plants and thus superior in protecting the oxygen level of the stream since it includes both sources of biological oxygen demand (the carbonaceous and nitrogenous) and allows credit for any dissolved oxygen in the effluent. A similar parameter ultimate biological oxygen demand (UBOD), can be used where no nitrogenous demand is expected. A third useful parameter to evaluate oxygen demand is chemical oxygen demand (COD). This test measures carbonaceous demand for oxygen from both biodegradable and nonbiodegradable compounds and is intended to prevent the discharge of slowly-degrading industrial waste. Consideration should be given to COD in effluents from POTW's which receive substantially nonbiodegradable industrial wastes.

SOURCES

CARBONACEOUS DEMAND



$$BOD_{ult} = 1.5\ (BOD_5)$$

NITROGENOUS DEMAND

$$\begin{tikzcd} NH_3 \arrow[d] & +\ 2O_2 \arrow[d] & = H^+ + NO_3^- + H_2O \\ NH_3 - N = 14 & O_2 = 64 & \end{tikzcd}$$

$$NOD_{ult} = \frac{64}{14}\ (NH_3\ N) = 4.6\ (NH_3 - N)$$

CREDIT

DISSOLVED OXYGEN = 1.0 (DO)

FORMULAS

$$UOD = 1.5\ (BOD_5) + 4.6 (NH_3\ N) - 1.0 (DO)$$

$$UBOD = 1.5 (BOD_5) - 1.0 (DO)$$

Figure 4. Derivation of Ultimate Oxygen Demand (UOD)

Carbonaceous oxygen demand is the largest source of biological-oxygen demanding-material in effluents from raw discharge or primary treatment, as Table 5 shows. In secondary treatment (high-rate system) as defined by EPA, the nitrogenous demand is by far the largest residual demand in the effluent. Thus, UOD as a means of measurement is particularly useful.

In addition to the treatment of wastewaters which pass through municipal plants, other approaches to improving water quality have been examined. These approaches include treating combined sewer overflows, treating storm water, and controlling non oint sources. Demonstrated technology to control storm water and nonpoint sources essentially does not exist. Efforts are being made to quantify the problems and identify the effects on receiving waters.

The combined sewer overflow problem is better quantified, and EPA research has demonstrated many types of treatment and control systems. On an amount basis, the cost of removing oxygen-demanding material by combined sewer overflow treatment is much greater than the cost of the same removal by increasing treatment at the plant (Table 6). This is always true on a yearly basis, but it is not always true on an event basis (Table 7). Also, the water quality benefits from overflow treatment are poorly documented. Overflow treatment and control needs vary greatly from one city to the next and can best be handled on a case-by-case basis. Systems with combined sewer overflows must be controlled to minimize the discharge of pollutants during wet-weather conditions.

A study conducted by EPA to determine the level of effluent quality required to ensure that 90 percent of the rivers and streams would meet dissolved oxygen (DO) criteria for fish and wildlife standards --5 milligrams per liter (mg/l) of DO--revealed that a yearly average of UOD of 33 mg/l was required. Statistically, this results in an approximate monthly average of 50 mg/l and a weekly average of 75 mg/l.

Table 5. Typical Values of Ultimate Oxygen Demand (UOD)

	Carbonaceous	Nitrogenous	Total (UOD)	% Removal
Raw	300	100	400	0
Primary	180	95	275	31
Secondary (High-Rate)	45	90	135	69
Secondary (Conventional)				
(Winter)	23	90	113	74
(Summer)	23	23	46	88
Two-Stage Nitrification	23	23	46	88
Advanced Waste Treatment+	8	12	20	95

Table 6. Yearly Capital Cost of Increased Treatment and Combined Sewer Overflow Control in Selected Cities

	Estimated Increased Treatment Cost[a] ($/pound UOD Removed/yr)	Overflow Controls Cost ($/pound UOD Removed/yr)
Cleveland, Ohio	0.21	2.22 (Filtration)
Oakland, Calif.	0.39	13.70 (Holding tanks) 13.60 (Sewer repair) 8.80 (Fine screening) 8.80 (System control)
Atlanta, Ga.	0.19	28.00 (Separate systems) 0.51 (Storage and screening) 1.34 (Storage and chlorination)
Bucyrus, Ohio	0.48	42.10 (Separate systems) 8.35 (Lagoons) 27.00 (Primary treatment)
New York City, N.Y.	0.98	2120 (Overflow control)
Kenosha, Wis.	0.22	11.80 (Storage and treatment) 23.80 (Storage and treatment)
Sacramento, Calif.	0.37	22.60 (Storage and Treatment)
Chippewa Falls, Wis.	0.46	19.80 (Storage and treatment)

a. Additional capital cost over secondary treatment to achieve seasonal nitrification.

Table 7. Capital Cost of Increased Treatment and Combined Sewer Overflow Control on a Yearly and Per-Storm-Only Basis[a]

COST ON A YEARLY BASIS		
	Estimated Increased Treatment Cost[b]	Overflow Control Cost
Capital Cost	$150,000	$895,000
UOD removed (pounds/year)	324,000	45,000
Cost ($/pound of UOD removed/year)	0.46	19.80
COST ON A PER STORM ONLY BASIS		
Capital Cost	$150,000	$895,000
UOD removed during storm only (pounds/storm)	111	4,905
Cost ($/pound of UOD removed/storm)	1,350	182

[a] Chippewa Falls, Wis., 5 ea. storm

[b] Additional capital cost over secondary treatment to achieve seasonal nitrification.

The cost for removing oxygen-demanding material from wastewater is economically reasonable up to 88 percent removal (Figure 5). Removals greater than this level result in much higher marginal costs per pound of pollutant removed.

The secondary treatment requirements in combination with water quality standards would offset the increased rate of UOD discharge associated with increased population (Figure 6).

The rate of biological oxygen removal resulting from the nitrifying action of ammonia varies dramatically with temperature (Figure 7). With very cold waters (either receiving waters or in wastewater being treated biologically), the nitrification process is slowed, reducing the importance of removing ammonia.

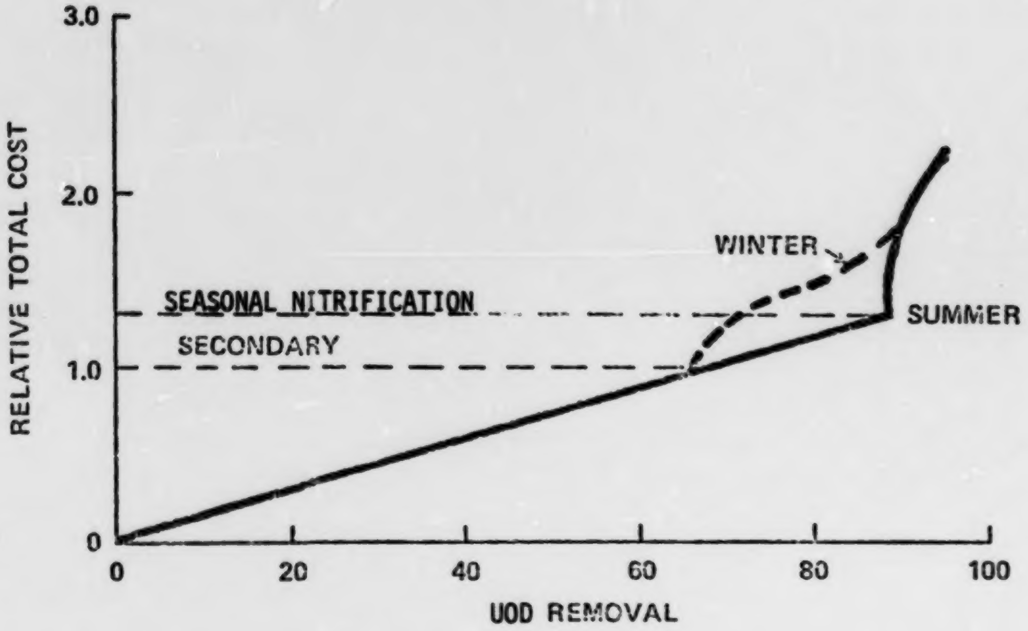


Figure 5. Cost vs. Percent of UOD Removed

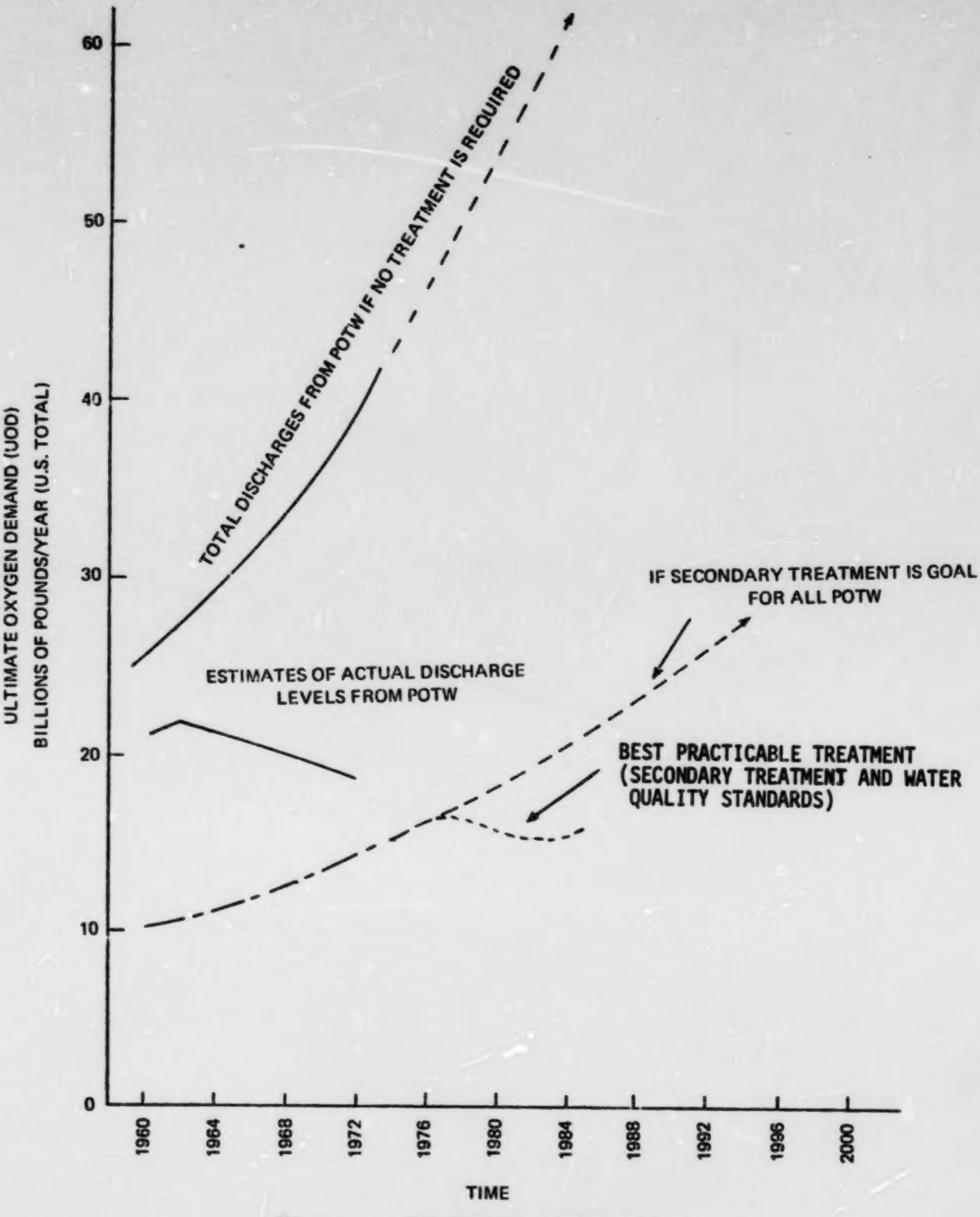


Figure UOD Removal, 1960--2000

41<

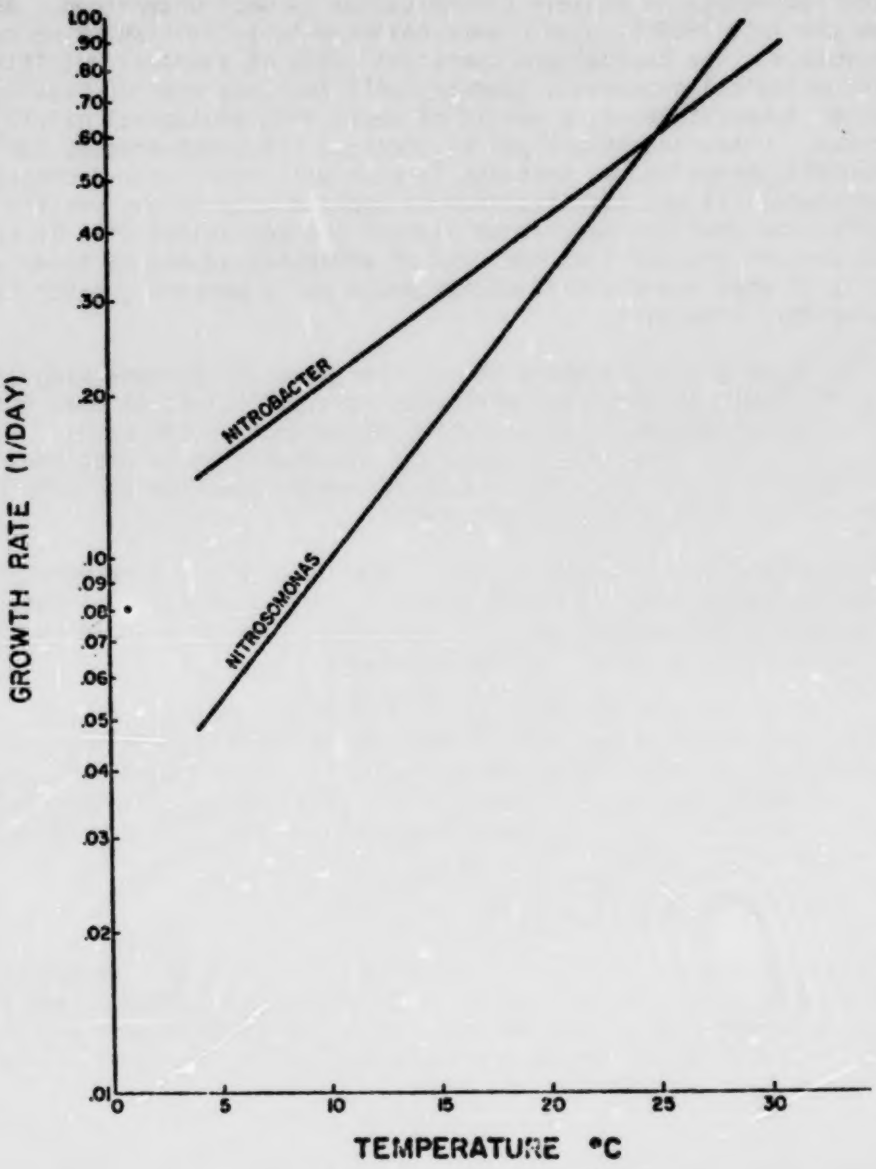


Figure 7. Effect of Temperature on the Growth Rate of Nitrifiers

As the environmental significance of ammonia diminishes with lower temperatures, the economic cost of satisfying its oxygen demand rises. The technology to achieve nitrification is well understood. As early as the late 1920's, plants were designed to accomplish 88 percent UOD removals. The capital and operating costs of seasonal nitrification in biological processes, however, will increase with decreasing wastewater temperature, as a result of decreasing biological nitrification rates. Likewise, in a physical-chemical treatment process such as ammonia stripping, an increase in cost will occur with decreasing temperature. If the nitrification is applied only to wastewaters above 20°C, the cost increase (both capital and operating) will be typically 30 percent greater than the cost of achieving secondary treatment. The cost of year round nitrification would be 75 percent greater than required secondary treatment.

In an EPA study where the discharge was to streams with intermittent or no flow, the nitrified effluents were sufficient to meet fish and wildlife standards in an estimated 90 percent of the cases. However, in only a few cases would secondary treatment levels meet these standards because of excessively low dissolved oxygen and fish toxicity caused by uncontrolled discharge of ammonia.

Nitrification would result in approximately a 50 percent increase in electrical power consumption for municipal waste treatment (Table 8). The resulting total demand for wastewater treatment would be less than 1 percent of the total community demand.

As a tradeoff for electrical demand, nitrification would produce less sludge and reduce fossil fuel requirements for incineration by approximately 25 percent (Table 8). Solid-waste management problems are likewise decreased. With a decrease of 25 percent in total sludge production, air pollution problems arising from incineration would be reduced as a result.

A. FLOW REDUCTION

Information on reducing the total flow of sewage is being prepared for a report to Congress pursuant to Section 104(o)(2) of the Act. The techniques discussed in that report should be recognized as part of the total area-wide waste management system and essential to achieving the best practicable treatment.

Table 8. Energy Requirements of Activated Sludge Treatment

	Secondary	Seasonal Nitrification	% Increase
Electrical			
Amount used	5 watts/cap	7.5 watts/cap	+ 50%
Percent of total electrical usage for a city	0.4%	0.6%	
Annual cost	44¢/cap/yr	66¢/cap/yr	
Fossil fuel to incinerate sludge			
Amount used	370 Btu/cap/day	280 Btu/cap/day	- 25%
Comparative usage	1 gal of fuel oil/cap/yr	3/4 gal of fuel oil/cap/yr	
Annual cost	12¢/cap/yr	9¢/cap/yr	

Excluding reuse and recycling, the techniques for reducing total flow of sewage can be placed into four major categories. The first technique is the reduction of infiltration and inflow into the sewage collection system. Infiltration problems must be solved, according to Section 201(g)(3) of the Act, before a Federal grant can be made. The procedures for complying with this section are contained in the regulations "Grants for Construction of Treatment Works" (40 CFR Part 35.927).

A second technique is the reduction of household water consumption. This involves installing devices to reduce water usage in existing household applicances and fixtures as well as designing and installing new applicances and fixtures that use less water. A third category of techniques involves economics and pricing policies to reduce use of water. The final techniques are the changes of public attitudes as they relate to water consumption.

B. TECHNIQUES TO ACHIEVE SECONDARY TREATMENT AND NITRIFICATION

Extensive amounts of information have been available since the 1920's on the biological techniques to achieve the effluent quality required by secondary treatment and nitrification. The techniques fall into four categories:

- Biological treatment, including ponds, activated sludge, and trickling filters.
- Physical-chemical, including chemical flocculation, filtration, activated carbon, breakpoint chlorination, ion exchange, and ammonia stripping.
- Land application with underdrains.
- Systems which combine the previous techniques.

Biological. The most widely used systems of waste-water treatment employ biological treatment. With the exception of anaerobic ponds, the systems use aerobic (air- or oxygen-requiring) metabolism to degrade the pollutants. Oxygen and bacterial cultures can be provided in many ways,

45<

including large shallow ponds exposed to the air, trickling filters with a bacterial culture supported on a rock or synthetic medium which is exposed to the atmosphere, and activated sludge, in which the culture of bacteria is aerated with air or oxygen.

a. Ponds. Sewage oxidation ponds, often called lagoons, are widely used throughout the United States. These systems require little energy because they rely on the natural forces such as aeration and produce minimum quantities of sludge. Since the design and operation of ponds vary widely, it is hard to generalize on their capabilities. A multicelled pond with intermittent-discharge capabilities can achieve secondary treatment and best practicable treatment without additional aeration or filtration if average loading does not exceed 20 pounds of BOD_5 per acre and if it has up to 6-month storage capability. However, this is not true of ponds which discharge continuously. Normally, ammonia is removed naturally; removal of BOD_5 and suspended solids is more difficult.

Ponds with lesser capabilities can employ mechanical aeration or rely on pretreatment (such as primary sedimentation) or postfiltration to achieve the required levels. High solids carryover, seasonal changes, algae growth, hydraulic short-circuiting, and overload conditions are problems which arise in many ponds and make achieving the standards more difficult.

In the 0.1- to 4.0-MGD size range, total costs for ponds range from $3 to $9 per person per year, versus $9 to $20 for activated sludge or trickling filters. Where land costs are high, however, ponds lose their cost advantages.

b. Activated sludge. The activated sludge process consists of an aerator and clarifier and is usually preceded by primary sedimentation. The aerator can be aerated by air (either diffused or mechanical) or pure oxygen and provides conditions for a suspended microbial growth which metabolizes the biodegradable wastes. The microbial growth is clarified and a portion recycled to maintain metabolism in the aerated tankage. The other portion (the build-up of microbial growth) and the primary solids go to an appropriate solids-handling facility. The use of chemicals--lime, ferric and ferrous salts, alum, sodium aluminate, or polymers--can enhance the capture of particulates in both primary

46<

sedimentation and secondary clarification, thus improving operation of the process. These techniques are examples of combined biological and physical-chemical treatment.

Activated sludge plants can be operated to establish and maintain bacteria to nitrify ammonia. This can be accomplished by supplying additional aeration, by ensuring that the nitrifying organisms propagate at a faster rate than they are destroyed, and by providing sufficient capacity in the aerator and/or clarifier to handle the higher mass of microbial growth resulting from the reduced wasting rate.

Several other new techniques have been employed to increase the capabilities of activated sludge plants without increasing the size of aerators or clarifiers. Rotating disks have been tested successfully in pilot plants. By using a disk, extra biological solids can be maintained in the aerator. A pilot plant in Tracy, Calif., used a synthetic or red wood media to allow a larger culture of bacteria to be maintained in the aerator. This minimizes the need for extra clarification.

Separate biological nitrification, which is basically similar to an activated sludge system, can also be used. The biodegradable wastes are largely reduced to approximately secondary quality in primary treatment. The aerobic microbial growth is then largely established and maintained on the metabolism of ammonia.

A separate nitrification stage is more reliable and can remove ammonia at much colder temperatures than the methods previously discussed. The capital and operational costs are expected to be 25 to 75 percent greater than single-stage systems.

Another new system, tested in pilot plants at Washington, D. C., and Central Contra Costa, Calif., uses chemical treatment to reduce the organic loading to the activated sludge aerator. The pilot results were excellent, with ammonia removed easily and reliably by nitrification. The system, however, does produce high quantities of sludge.

Still another system using combined biological and physical-chemical methods is to employ breakpoint chlorination or ion exchange (both discussed later) to remove the ammonia from a nonnitrifying biological plant to acceptable levels.

c. Trickling filters. Trickling filter plants are similar to activated sludge plants except that microbial growth is not suspended. Instead it is attached to a fixed medium, such as rocks or a synthetic material, over which the wastewater is repeatedly recycled. The excessive microbial growth is sloughed off of the media and captured in a clarifier. Trickling filters employing standard loadings below 10 to 20 pounds of BOD_5 per 1,000 cubic feet of medium per day can meet secondary and best-practicable-treatment requirements. The performance and costs are generally competitive with equivalent activated sludge systems.

A modification of the trickling filter concept involves rotating closely packed disks through the sewage. Large masses of bacteria are maintained and aerated on the disk during rotation. Initial work in Passaic Valley, N.J., Pewaukee, Wis., and at the University of Michigan have demonstrated the system's capabilities.

Physical-Chemical. Chemical flocculation of suspended and colloidal solids (using lime, ferric or ferrous salts, alum, and sodium aluminate, often with polymer addition and subsequent sedimentation) can often achieve effluent quality equivalent to secondary treatment. Subsequent filtration may be needed, although not in all cases.

Suspended solids and the associated BOD can be removed by filtration in any of the methods discussed to improve the effluent quality above secondary treatment. A wide selection of filtration media is available. Either pressure or gravity filtration can be used. Removal of suspended solids is usually desirable prior to activated carbon, breakpoint chlorination, ion exchange, or ammonia stripping.

Activated carbon has proven its ability to adsorb the organic material in wastewater. Because activated carbon does not rely on bacterial action, it can remove both biodegradable and nonbiodegradable material.

Several techniques have been used to bring the activated carbon into contact with the wastewater, and various forms of carbon have been used. Granular carbon is the most widely-used and highly-developed technique. Contact methods include pressurized downflow, gravity downflow, and pressurized suspended-bed upflow. Powdered carbon systems can also be used, and show excellent potential, although still in the research and development stage.

48<

Breakpoint chlorination (superchlorination) can be used to reduce ammonia concentrations in wastewater. Chlorine, sodium hypochlorite, and calcium hypochlorite can be added at ratios between 7.6:1 and 10:1 of chlorine to ammonia nitrogen. This will oxidize the ammonia to nitrogen gas if reaction takes place at about pH 7. Proper controls and operation must be maintained at all times.

Selective ion exchange systems are available for removal of ammonia. The ion exchange medium normally used is clinotilolite. After regeneration with a salt and/or lime brine, it will exchange either the sodium ion or calcium ion for the ammonium ion in wastewater. The regeneration brine contains the removed ammonia. The removal from and the disposal of ammonia can be accomplished by steam distillation and subsequent condensation and recovery of ammonium hydroxide. Electrolytic or chlorine oxidation of the ammonia in the brine to nitrogen gas has been demonstrated in pilot studies. Hot air stripping of ammonia from the brine, followed by acid readsorption and precipitation of ammonia salts, has also been investigated. The salts can be used as fertilizer.

Ammonia can be stripped from wastewater although it requires 100 to 800 cubic feet of air per gallon of water. The ammonia is usually discharged directly to the atmosphere, but this practice should be avoided in areas where the discharge could degrade the quality of the atmosphere. The process has other disadvantages. Lime must be added to the influent before the ammonia can be stripped. Further, effectiveness of stripping decreases with decreasing atmospheric temperature.

Land Application. Often land treatment is not thought of as a treatment and discharge process. However, an underdrain or similar water removal procedure used with overland flow can achieve the effluent quality required by secondary treatment and best practicable treatment standards. This technique is presently being demonstrated in Muskegon County, Michigan.

C. STORM AND COMBINED-SEWER CONTROL

Storm and combined-sewer overflows can be a source of significant quantities of pollutants. Demonstrated technology to control storm sewer discharges does not exist. Efforts are being made to quantify the problem and identify the effect on receiving waters.

49<

The combined-sewer overflow problem is better quantified, and EPA research has demonstrated many types of control and treatment techniques. The techniques fall into five categories: (1) separation of sewage and storm collection systems, (2) operational control of the existing system, (3) storage and subsequent treatment, (4) dual use, and (5) direct treatment of overflows. Combinations of the techniques often result in the most cost-effective solutions, as has been demonstrated in Atlanta, Ga., and Bucyrus, Ohio.

Separation of Combined Sewers. One approach to minimizing overflows from combined sewers is to separate the systems. Complete separation is the most costly. In 1964, the cost for separating sewers in 16 cities was estimated at $9.6 billion (Table 9), for an average cost of $468 per person. The 1964 estimate for the U.S. was $25 to $30 billion. Today, the cost may be in excess of $50 billion.

Another approach would be to partially separate the systems in a cost-effective manner. Partial separation includes separation of roof drains, area drains, foundation drains, air conditioning drains, and yard drains. This procedure would have cost $176 per person in 1964 (Table 10), or a total U.S. cost of $10.4 billion. The cost now may be in excess of $20 billion.

Control of Combined Sewers. Proper design, maintenance, and control of combined sewers (as now required for best practicable treatment) can markedly reduce the discharge of pollutants. A manual of practice prepared by the American Public Works Association for the Federal water pollution control program points to design and maintenance practices as the key to minimizing overflow pollution. Also, a study of the Hudson River concluded that proper maintenance of valves and other flow-regulating devices could substantially reduce overflows.

Table 9. Estimated Costs for Complete Separation of Stormwater and Sanitary Sewers

City	Total Project Cost	Cost/acre	Cost/ capita
Chicago, Ill.	$2,300,000,000	$17,000	$482
Cleveland, Ohio	470,000,000- 700,000,000	12,000- 18,000	360-535
Concord, N.H.	8,000,000	. . . .	280
Detroit, Mich.	1,315,000,000	. . . .	360
Haverhill, Mass.	30,000,000	10,500	650
Kansas City, Kans.	20,000,000	7,745[a]	187
Lawrence, Kans.	30,000,000	13,500	915
Lowell, Mass.	70,000,000	12,000	780
Milwaukee, Wis.	425,000,000	8,250	440
New Haven, Conn.	10,000,000	16,363[a]	560
New York, N.Y.	4,000,000,000	25,000- 30,000	492
Portland, Ore.	100,000,000 250,000,000	3,100- 7,750	260-652
Seattle, Wash.	145,000,000	3,890	260
Spokane, Wash.	50,000,000	1,800	415
Toronto, Ontario	285,000,000	17,000	. . . .
Washington, D.C.	214,000,000	18,000	250
Total	9,662,000,000[b]	12,427[b]	468[b]

a. Based on actual project cost.

b. Using the average costs for those cities reporting ranges.

51<

Table 10. Estimated Costs for Partial Separation of Stormwater and Sanitary Sewers

City	Total project cost	Cost/ acre	Cost/ capita
Des Moines, Iowa	$25,000,000	$7,800	$170
Elmhurst, Ill.	8,770,000	. . .	237
Eugene, Ore.	3,410,000	3,100	76
Findlay, Ohio	15,108,000	. . .	500
Granite City, Ill.	13,200,000	4,900	330
Hannibal, Mo.	613,000	. . .	43
Kendallville, Ind.	969,000	. . .	143
Lafayette, Ind.	5,024,000	. . .	120
La Porte, Ind.	9,187,000	. . .	437
Lathrup Village, Mich.	961,500	. . .	302
Louisville, Ky.	30,538,000	. . .	73
Michigan City, Ind.	3,500,000	. . .	95
Minneapolis, Minn.	30,000,000	3,040	69
Mishawaka, Ind.	4,392,000	972	129
Napa, Colo	1,549,000	640	52
Sedalia, Mo.	4,470,000	. . .	213
Seattle, Wash.	69,000,000	1,860	124
Tacoma, Wash.	7,960,000	. . .	53
Total	233,651,500	3,187[a]	176[a]

a. Average.

An even more effective control technique is regulating combined collection systems so as to utilize their capacity to the utmost. For example, Metro-Seattle uses continuous flow measurements and computerized control to divert flow to portions of the system that are under-utilized. A similar system operated by the Minneapolis-St. Paul Sanitary District (now the Metropolitan Sewer Board) reduced the quantities of overflow by 66 percent and the duration by 88 percent. The control system cost $1.75 million and had approximately the effect of a separation project costing $200 million.

Another control system which has experimentally shown promise of reducing pollution is periodic flushing of sewers during dry weather. Flushing is estimated to cost between $620 and $1,275 per acre (in 1972) and can substantially reduce the wash out and overflow of the deposited materials from the system.

Storage and Treatment of Combined Overflows. An excellent way to eliminate or reduce combined overflows is to store and subsequently treat the overflows. This technique was successfully demonstrated in Chippewa Falls, Wis. An asphalt-paved detention basin was built to retain overflows up to a 5-year storm. The system captured 93.7 percent of the quantity of overflow, which was treated in the wastewater treatment plant during low-flow periods. The capital cost in 1972 was $6,780 per sewered acre.

Other storage devices have been tested. In Cambridge, Md., a 200,000-gallon flexible underwater container stores combined sewer overflows. This device contained 96 percent of the overflow for subsequent treatment. The capital cost was $1.85 per 1,000 gallons captured.

Dual Use. Several methods have been used to directly treat the overflow from combined sewers. In Kenosha, Wis., the existing wastewater treatment plant is operated to maximize biological adsorption in the aerator during wet-weather flows. The adsorped organics are later biologically degraded. Prior to construction of the dual-use facility, removals of suspended solids and BOD_5 were 64 and 82 percent, respectively. Following construction, removals were 88 and 94 percent. During wet weather, the plant still removes 91 percent of suspended solids and 82.5 percent of BOD_5. This technique cost $917 per sewered acre and was $7 million

53<

cheaper than separation. Another technique is to expand the wastewater plant so it can treat overflows, either partially or fully. The District of Columbia has designed primary sedimentation tanks to handle excessive wet-weather flows. The excessive flows will receive primary treatment and chlorination.

Treatment of Combined Overflows. Other techniques have shown capability of treating excessive wet-weather flows where land is scarce. One such technique is high-rate dual-media filtration. Experimental results showed 93 percent removal of suspended solids and 65 percent removal of BOD_5 at high filter rates. In 1971, estimated capital cost for this system was approximately $23,000 per MGD of design capacity. The expected operational cost was $90,000 per year for a 25-MGD plant to $390,000 for a 200-MGD plant. Another technique uses a rotating fine screen. In pilot plant tests, 34 percent of suspended solids, 27 percent of COD, and 99 percent of floatable and settleable solids were removed. The estimated cost for a 25-MGD plant is 22 cents per 1,000 gallons treated. In-sewer fixed screens with screen openings ranging from 1/8 inch to 1 inch have been tested, with varying degrees of success. Chemical treatment using polyelectrolytes, lime, alum, or ferric chloride is also being investigated to help treat excessive wet-weather flows.

Another treatment technique is disinfection. Chlorine gas can be used just as it is in wastewater treatment plants. Recently, however, electrochemical cells have been used to produce hypochlorite disinfectant in isolated or unattended installations. The cell uses 1.6 kilowatt hours of electricity and 2.1 pounds of salt per pound of sodium hypochlorite produced. Large installations are expected to produce chlorine for 3 to 4 cents per pound.

D. ADVANCED WASTE TREATMENT (NUTRIENT REMOVAL)

The term "advanced waste treatment" is used in many different ways. In this report the term is used to describe unit processes or systems designed to prevent the discharge of pollutants or nutrients which can cause accelerated euthrophication of the receiving waters. The key nutrients are carbon, nitrogen, and phosphorus. Euthrophication may be a significant problem in certain receiving waters. Nutrient removal, however, is not required by best practicable treatment on a national basis. Advanced waste treatment (or nutrient removal) techniques are usually used in conjunction with the techniques to achieve secondary treatment. The techniques fall into four categories--biological, physical-chemical, land application, and combinations.

Biological. Biological methods to remove carbon are the same techniques discussed earlier--ponds, activated sludge, and trickling filters. When higher degrees of removal are necessary, however, longer detention periods are required or improved liquid solids techniques such as larger clarifiers or filtration must be employed. The biological method to remove nitrogen is nitrification followed by denitrification. Both can be accomplished in a mixed suspended culture followed by clarification (similar to activated sludge) or on a fixed media (similar to a trickling filter). The Blue Plains Plant at Washington, D. C., is currently building a 300-MGD biological nitrification and denitrification system. Separate denitrification requires an organic supplement. Methanol has been most commonly used. For successful operation, approximately 3.5 parts of methanol are required to each part of nitrate nitrogen. Both nitrification and denitrification are temperature-sensitive. At 10°C, the metabolic kinetic rates can decrease to less than 20 percent of the rates observed at 30°C. Normally, nitrogen cannot be removed by a single-stage biological process. However, in recent experiments at a pilot plant in Washington, D. C., an intermittently-pulsed aerobic and anaerobic system removed up to 80 percent of the nitrogen, thus drastically reducing the methanol requirements.

Recent experiments at Washington have shown that biological removal of phosphorus can be achieved. Less than 0.5 mg/l of phosphorus remained in the effluent. The system couples conventional aeration with rapid removal of solids from the clarifier. The solids are then aerobically digested for 6 to 20 hours; the phosphorus in the sludge is released and precipitated in the side stream. The solids are then recycled to the aeration tank.

Physical-Chemical. Physical-chemical methods are probably the most widely relied on in advanced waste treatment. Carbon in large complex molecules can be removed from wastewater by carbon adsorption. BOD_5 of 5 mg/l or less can be achieved. Gravity flow, pressurized downward flow, and pressurized upflow contact methods have been demonstrated utilizing a variety of size and gradation of media. The Piscataway, Md., plant is using carbon adsorption in a 5-MGD advanced waste treatment facility. Also, ozone oxidation of organic carbon has been shown to reduce the BOD_5 to substantially less than 5 mg/l in experiments in Washington.

55<

The physical-chemical removal techniques for nitrogen include breakpoint chlorination, ion exchange, and ammonia stripping. Effluents containing less than 2.5 mg/l of total nitrogen have been produced with these techniques. Tests on breakpoint chlorination were conducted at Washington, and the method is being proposed for facilities in Cortland, N.Y.; Montgomery County, Maryland; Gainesville, Fla.; Bucks County, Pennsylvania; and Occoquan, Va. Ion exchange is being considered in Alexandria, Va., and Neosho, Mo. Ammonia stripping has already been used on full-scale installations in Orange County and South Lake Tahoe, Calif.

Lime, ferric salts, alum and aluminum salts are used in the physical-chemical methods of removing phosphorus. Addition of the chemical and precipitation can be done throughout the process--in primary sedimentation, in the secondary system, or as a separate final stage (often termed tertiary treatment). Many plants around the Great Lakes are using ferric and alum salts in either primary or secondary stages to reduce phosphorus. Lime can be used in primary sedimentation for phosphorus removal, as demonstrated in pilot studies in Washington, or as separate tertiary treatment as currently being employed in a 5-MGD plant in Piscataway, Md.

Land Application. Land application techniques discussed earlier can be designed and operated as advanced waste treatment systems. Nutrients are removed as the wastewater comes in contact with the soil and are then available to plant life.

IV. REUSE TECHNIQUES

One of the major techniques for handling wastewater is wastewater reuse and by-product recovery. Uniform criteria for best practicable treatment cannot be set for reuse purposes. For some industrial reuse purposes such as cooling or quenching, no treatment of domestic wastewater is required. Other reuse purposes require water to be of drinking-water quality or better.

The reuse criteria for best practicable treatment are set according to the medium (land or surface waters) into which reuse water is ultimately discharged. They reflect two considerations. First, as a minimum, criteria for reuse should result in no greater pollutional effect than if treatment and discharge or land application criteria were employed. This is to ensure equity among municipal works and prevent degradation of the receiving waters through the indirect discharge of untreated domestic waste. Second, as a maximum, criteria for reuse should impose as few additional restrictions as possible. This is to carry out the purpose stated in the Act to encourage wastewater reuse, particularly when such facilities will produce revenue.

For the above reasons, the reuse criteria for best practicable treatment require that the quantity of pollutants discharged from a reuse project, attributable directly to the publicly-owned treatment works, meet the minimum criteria for non-reuse techniques.

A. REUSE OF WASTEWATER

Reuse opportunities from wastewater treatment plants do not only include reuse of the effluent. Use of methane gas from anaerobic digestion, recovery of coagulant in systems employing lime precipitation, and regeneration of activated carbon are also possible. The reuse of wastewater effluent, however, is still the most important.

The effuent quality required for reuse may vary as discussed earlier. In many cases, reuse may require additional treatment beyond nutrient removal. Often the problem is high dissolved-solids concentration. Several methods have been proposed. Distillation, ion exchange, and freezing techniques are still in the research or small-scale pilot stage. The most advanced technology of dissolved-solids removal is reverse osmosis.

A major steel industry in Baltimore, Md. requires no pretreatment. The industry treats to its needs. Other systems, such as one being planned at the Central Costa Sanitary District, Calif., require advanced waste treatment prior to industrial reuse. The latter facility is expected to be revenue-producing.

Recharging ground water, directly or indirectly, is also a potential reuse. This is being practiced with increasing frequency in the arid southwest. Also, in the East, Long Island, N.Y. is recognizing the need for ground water recharge and is planning a demonstration study. Similarly, the prevention of salt water intrusion is an excellent reuse opportunity. Direct reuse for drinking water is being practiced in Windhok, South Africa. It is not being practiced in this country.

Another wastewater reuse is in development of arid land. Examples include grassland or golf courses watered with treated effluent, development of forest land being researched at the University of Pennsylvania, and a recreation facility developed by Los Angeles County in Antelope Valley, Calif. New land application techniques are expected to provide conditions for producing sod, Christmas trees, hay, or even beef cattle. The treated effluent from the South Lake Tahoe, Calif. plant is pumped to a reservoir for eventual irrigation. Highly-treated wastewater from the proposed Upper Occoquan, Va. plant will be discharged to a reservoir used for water supply.

Revenue-producing facilities are being considered with increasing frequency. A plant in the Central Contra Costa Sanitary District, Calif., is in the early design stage. It is expected to sell highly-treated effluent to industries, saving major development of new water supplies.

B. REUSE OF OTHER TREATMENT-PLANT WASTES

Reuse of treatment-plant wastes such as sludges, methane gas and waste activated carbon is also possible. For several decades, methane gas from anaerobic digestion of sludge has been used for fuel, for electrical power generation and heat.

Sludge can also be reused. In Milwaukee, Wis., dried sludge has been sold as a soil builder, thus producing revenue. This is a unique operation. Another technique, demonstrated in pilot studies in Washington, D. C. and in full-scale operations at Piscataway, Md., and South Lake Tahoe, Calif., recovers coagulant from a lime precipitation process. The organic sludge is incinerated and the calcium carbonate that results from lime precipitation is calcined back to lime for subsequent reuse. South Lake Tahoe also has facilities to reactivate the activated carbon spent in wastewater treatment.

Other sludge-reuse techniques are also being investigated. One such system is the acid treatment of alum sludges to recover alum: this system is actually being used in Japan. Hydrolysis of organic sludges shows potential in producing animal feed. Sulfur dioxide, heat and pressure are employed. After the hydrolysis, evaporation concentrates digestible organics valued at 2 to 5 cents per pound. Organic and chemical sludges can also be used to condition barren soil and improve cash-crop potential.

C. INTEGRATED REUSE FACILITIES

Reuse techniques benefit from total area planning and increasing utilization of integrated facilities. One potential integrated facility is the proposed Delaware Reclamation Project, where wastewater treatment sludges, municipal refuse, and garbage would be composted, separated, and heat-treated. At another proposed facility in Montgomery County, Md., organic sludges would be pretreated and used as a supplemental fuel source in thermoelectric power production. The effluent could also be used to supplement cooling water. Other integrated concepts which have been widely used are incorporation of septic-tank treatment capabilities in a plant and the use of joint municipal and industrial treatment facilities.

APPENDIX A - BIBLIOGRAPHY

I. GENERAL INFORMATION

The Law

Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500).

Regulations

"Secondary Treatment Information" (40 CFR 133) published in the Federal Register on August 17, 1973.

"Cost-Effectiveness Analysis" (40 CFR 35 Appendix A) published in the Federal Register on September 10, 1973.

"Grants for Construction of Treatment Works" (40 CFR 35) published as interim regulations in the Federal Register on February 28, 1973.

"State Continuing Planning Process" (40 CFR 130) published as interim regulations in the Federal Register on March 27, 1973.

Agency Programs

Municipal Construction Division
Office of Air and Water Programs, Environmental Protection Agency
Washington, D. C. 20460.

Municipal Pollution Control Division
Office of Research and Development, Environmental Protection Agency
Washington, D. C. 20460.

Technology Transfer Staff
Office of Research and Development, Environmental Protection Agency
Washington, D. C. 20460.

Research Information Division
Office of Research and Development, Environmental Protection Agency
Washington, D. C. 20460.

Federal Bibliographic Sources

"Bibliography of R and M Research Reports"
Research Information Division, Office of Research and Development
Environmental Protection Agency, Washington, D. C. 20460.

"Selected Water Resources Abstracts", published Semimonthly by the
Water Resources Scientific Information Center, U.S. Department of
the Interior, Washington, D. C. 20240.

Notice

Publication of the following bibliographic information has been approved by the Environmental Protection Agency does not necessarily signify that the items in the bibliography reflect the views and policies of the Environmental Protection Agency, nor does the mention of trade names or commercial products constitute endorsement or recommendation for use.

II. LAND APPLICATION TECHNIQUES

Bibliographies

"Wastewater Treatment and Reuse by Land Application - Bibliography" prepared by Metcalf and Eddy, Inc. for the Environmental Protection Agency, May 1973.

"Bibliography - Survey of Facilities Using Land Application" prepared by the American Public Works Association for the Environmental Protection Agency, April 1973.

"Land Application of Sewage Effluents and Sludges: Selected Abstracts" being prepared by the Environmental Protection Agency, May 1974 (proposed date).

Bibliographic List

1. Allen, M.L., "North Tahoe Agencies Test Disposal in Volcanic Cinder Cone," Bulletin Calif. Water Pollution Control Assoc., 9, No. 3, pp 31-38 (January 1973).

2. Allender, G.C., "The Cost of a Spray Irrigation System for the Renovation of Treated Municipal Wastewater," Master's Thesis, The Pennsylvania State Univ., (September 1972).

3. Amramy, A., "Waste Treatment for Groundwater Recharge," Jour. WPCF, 36, No. 3, pp 296-298 (1964).

4. Anderson, D.R., et al., "Percolation of Citrus Wastes through Soil," Proceedings of the 21st Industrial Waste Conference, Part II, Purdue University, Lafayette, Indiana, pp 892-901 (1966).

5. "Assessment of the Effectiveness and Effects of Land Disposal Methodologies of Wastewater Management," Department of the Army, Corps of Engineers, Wastewater Management Report 72-1 (January 1972).

6. Aulenbach, D.B., Glavin, T.P., and Rojas, J.A.R., "Effectiveness of a Deep Natural Sand Filter for Finishing of a Secondary Treatment Plant Effluent," Presented at the New York Water Pollution Control Association Meeting (January 29, 1970).

8. Baffa, J.J., and Bartilucci, N.J., "Wastewater Reclamation by Groundwater Recharge on Long Island," Jour. WPCF, 39, No. 3, pp 431-445 (1967).

9. Bendixen, T.W., et al., "Cannery Waste Treatment by Spray Irrigation Runoff," Jour. WPCF, 41, No. 3, pp 385-391 (1969).

10. Bendixen, T.W., et al., "Ridge and Furrow Liquid Waste Disposal in a Northern Latitude," ASCE San. Engr. Div., 94, No. SA 1, pp 147-157 (1968).

11. Blaney, H.F., and Criddle, W.D., "Determining Consumptive Use and Irrigation Water Requirements," Tech. Bull. No. 1275, U.S. Dept. of Agriculture, Washington, D.C. (December 1962).

12. Blosser, R.O., and Owens, E.L., "Irrigation and Land Disposal of Pulp Mill Effluents," *Water and Sewage Works*, *III*, No. 9, pp 424-432 (1964).

13. Borushko, I.S., "The Influence of a Water Body on the Temperature and Air Humidity of the Surrounding Territory," *Tr. Glavn. Geofizich. Observatorii*, No. 59 (121), Leningrad: Gidrometeoizdat (1956).

14. Bouwer, H., "Ground Water Recharge Design for Renovating Waste Water," *ASCE San. Engr. Div.*, *96*, No. SA 1, pp 59-74 (1970).

15. Bouwer, H., "Renovating Secondary Effluent by Groundwater Recharge with Infiltration Basins," Presented at the Symposium on Recycling Treated Municipal Wastewater and Sludge through Forest and Cropland," The Pennsylvania State University, University Park, Pennsylvania (August 21-24, 1972).

16. Bouwer, H., "Water Quality Aspects of Intermittent Systems Using Secondary Sewage Effluent," Presented at the Artificial Groundwater Recharge Conference, University of Reading, England (September 21-24, 1970).

17. Bureau of Sanitary Engineering, "Waste Water Reclamation," California State Department of Public Health, Prepared for Calif. State Water Quality Control Board (November 1967).

18. Bureau of Water Quality Management, *Spray Irrigation Manual*, Pennsylvania Dept. of Environmental Resources, Publication No. 31 (1972).

19. Buxton, J.L., "Determination of a Cost for Reclaiming Sewage Effluent by Ground Water Recharge in Phoenix, Arizona," Master's Thesis, Arizona State University (June 1969).

20. Canham, R.A., "Comminuted Solids Inclusion with Spray Irrigated Canning Waste," *Sewage & Industrial Wastes*, *30*, No. 8, pp 1028-1049 (1958).

21. Center for the Study of Federalism, *Green Land--Clean Streams: The Beneficial Use of Waste Water through Land Treatment*, Stevens, R.M., Temple University, Philadelphia, Pennsylvania (1972).

22. Coast Laboratories, "Grape Stillage Disposal by Intermittent Irrigation," Prepared for the Wine Institute, San Francisco, Calif. (June 1947).

23. Coerver, J.F., "Health Regulations Concerning Sewage Effluent for Irrigation," Proceedings of the Symposium on Municipal Sewage Effluent for Irrigation, Louisiana Polytechnic Institution (July 30, 1968).

24. C.W. Thornthwaite Associates, "An Evaluation of Cannery Waste Disposal by Overland Flow Spray Irrigation," Publications in Climatology, 22, No. 2 (September 1969).

25. DeTurk, E.E., "Adaptability of Sewage Sludge as a Fertilizer," Sewage Works Journal, 7, No. 4, pp 597-610 (1935).

26. De Vries, J., "Soil Filtration of Wastewater Effluent and the Mechanism of Pore Clogging," Jour. WPCF, 44, No. 4, pp 565-573 (1972).

27. Drake, J.A., and Bieri, F.K., "Disposal of Liquid Wastes by the Irrigation Method at Vegetable Canning Plants in Minnesota 1948-1950," Proceedings of the 6th Industrial Waste Conference, Purdue University, Lafayette, Indiana, pp 70-79 (1951).

28. Drewry, W.A., and Eliassen, R., "Virus Movement in Groundwater," Jour. WPCF, 40, No. 8, Part 2, pp R257-R271 (1968).

29. Dubrovin, L.V., "Computation of the Influence of a Reservoir on Absolute Humidity in the Littoral Zone," Materialy Pervogo Nauchno-tekhnicheskogo Soveshchaniya Po Izercheniyu Kuybyshevskogo Vodokhranilishcha, No. 2, Kuybyshev (1963).

30. Duffer, W., "EPA Supported Research," Presented at the Symposium on Land Disposal of Municipal Effluents and Sludges, Rutgers University, New Brunswick, New Jersey (March 12-13, 1973).

31. Dunlop, S.G., "Survival of Pathogens and Related Disease Hazards," Proceedings of the Symposium on Municipal Sewage Effluent for Irrigation, Louisiana Polytechnic Institution (July 30, 1968).

32. Ebbert, S.A., "Spray Irrigation of Food Plant Waste Waters," Presented at the 30th Annual Meeting, Federation of Sewage and Industrial Wastes Associations, University Park, Pennsylvania (August 13-15, 1958).

33. Eliassen, R., et al., "Studies on the Movement of Viruses with Groundwater," Water Quality Control Research Laboratory, Stanford University (1967).

34. "Engineering Feasibility Demonstration Study for Muskegon County, Michigan Wastewater Treatment - Irrigation System," Muskegon County Board and Department of Public Works, Federal Water Quality Administration, Program No. 11010 FMY (September 1970).

35. Fisk, W.W., "Food Processing Waste Disposal," *Water and Sewage Works*, *III*, No. 9, pp 417-420 (1964).

36. Foster, H.B., Ward, P.C., and Prucha, A.A., "Nutrient Removal by Effluent Spraying," *ASCE San. Engr. Div.*, *91*, No. SA 6, pp 1-12 (1965).

37. Fried, M., and Broeshart, H., *The Soil-Plant System in Relation to Inorganic Nutrition*, Academic Press, New York (1967).

38. Gilde, L.C., et al., "A Spray Irrigation System for Treatment of Cannery Wastes," *Jour. WPCF*, *43*, No. 8, pp 2011-2025 (1971).

39. Gillespie, C.G., "Simple Application of Fundamental Principles of Sewage Treatment," *Sewage Works Journal*, *1*, No. 1, p 68 (1928).

40. Gotaas, H.B., "Field Investigation of Waste Water Reclamation in Relation to Ground Water Pollution," Calif. State Water Pollution Control Board, Publication No. 6 (1953).

41. Gotaas, H.B., et al., "Annual Report on Investigation of Travel of Pollution," Sanitary Engineering Research Project, University of California, Berkeley (1953).

42. Gray, J.F., "Practical Irrigation with Sewage Effluent," *Proceedings of the Symposium on Municipal Sewage Effluent for Irrigation*, Louisiana Polytechnic Institution (July 30, 1968).

43. Guerri, E.A., "Sprayfield Application Handles Spent Pulping Liquors Efficiently," *Pulp & Paper*, *45*, No. 2, pp 93-95 (1971).

44. Haas, F.C., "Spray Irrigation Treatment," *Proceedings of Symposium on Potato Waste Treatment*, University of Idaho and FWPCA, U.S. Dept. of the Interior (July 1968).

45. Hill, R.D., Bendixen, T.W., and Robeck, G.G., "Status of Land Treatment for Liquid Waste--Functional Design," Presented at the Water Pollution Control Federation Conference, Bal Harbour, Florida (October 1964).

46. Huff, F.A., et al., "Effect of Cooling Tower Effluents on Atmospheric Conditions in Northeastern Illinois," *Illinois State Water Survey, Circular 100*, Dept. of Registration and Education (1971).

47. Hutchins, W.A., "Sewage Irrigation as Practiced in the Western States," Technical Bulletin No. 675, U.S. Dept. of Agriculture (March 1939).

48. Hyde, C.G., "The Beautification and Irrigation of Golden Gate Park with Activated Sludge Effluent," *Sewage Works Journal*, *9*, No. 6, pp 929-941 (1937).

49. Kardos, L.T., "Crop Response to Sewage Effluent," *Proceedings of the Symposium on Municipal Sewage Effluent for Irrigation*, Louisiana Polytechnic Institution (July 30, 1968).

50. Kaufman, W.J., "Notes on Chemical Pollution of Ground-Water," Presented at the Water Resources Engineering Educational Series, Program X, Groundwater Pollution, San Francisco, California (January 1973).

51. Kirby, C.F., "Sewage Treatment Farms," Dept. of Civil Engineering, University of Melbourne (1971).

52. Kolobov, N.V., and Vereshchagin, M.A., "The Influence of Kuybyshev and Volgograd Reservoirs on Meteorological Conditions in the Littoral Zone," *Materialy Pervogo Nauchno-tekhnicheskogo Soveshchaniya Po Izucheniyu Kuybyshevskogo Vodokhranilishcha*, No. 2 Kuybyshev (1963).

54. Krone, R.B., McGauhey, P.H., and Gotaas, H.B., "Direct Discharge of Ground Water with Sewage Effluents," ASCE San. Engr. Div., 83, No. SA 4, pp 1-25 (1957).

55. Krone, R.B., Orlob, G.T., and Hodgkinson, C., "Movement of Coliform Bacteria through Porous Media," Sewage and Industrial Wastes, 30, No. 1, pp 1-13 (1958).

56. Lance, J.C., "Nitrogen Removal by Soil Mechanisms," Jour. WPCF, 44, No. 7, pp 1352-1361 (1972).

57. Larson, W.C., "Spray Irrigation for the Removal of Nutrients in Sewage Treatment Plant Effluent as Practiced at Detroit Lakes, Minnesota," Algae and Metropolitan Wastes, Transactions of the 1960 Seminar, U.S. Dept. of HEW (1960).

58. Laverty, F.B., et al., "Reclaiming Hyperion Effluent," ASCE San. Engr. Div., 87, No. SA 6, pp 1-40 (1961).

59. Lawton, G.W., et al., "Spray Irrigation of Dairy Wastes," Sewage & Industrial Wastes, 31, No. 8, pp 923-933 (1959).

60. Linsley, R.K., Kohler, M.A., and Paulhus, J.L.H., Hydrology for Engineers, McGraw-Hill, New York, pp 122-132 (1958).

61. "Liquid Wastes from Canning and Freezing Fruits and Vegetables," National Canners Association, Office of Research and Monitoring, Environmental Protection Agency, Program No. 12060 EDK, pp 61-65, 73-74 (August 1971).

62. Ludwig, H., et al., "Disposal of Citrus Byproducts Wastes at Ontario, California," Sewage & Industrial Wastes, 23, No. 10, pp 1255-1266 (1951).

63. McCarty, P.L., and King, P.H., "The Movement of Pesticides in Soils," Proceedings of the 21st Industrial Waste Conference, Part 1, Purdue University, Lafayette, Indiana, pp 156-171 (1966).

64. McDonald, J.E., "The Evaporation-Percolation Fallacy," Weather, 17, No. 5, pp 168-177 (1962).

65. McGauhey, P.H., and Krone, R.B., "Soil Mantle as a Wastewater Treatment System," SERL Report No. 67-11, University of California, Berkeley (December 1967).

66. McGauhey, P.H., and Winneberger, J.H., "A Study of Methods of Preventing Failure of Septic-Tank Percolation Systems," SERL Report No. 65-17, University of California, Berkeley (October 1965).

69. McMichael, F.C., and McKee, J.E., "Wastewater Reclamation at Whittier Narrows," Calif. State Water Quality Control Board, Publication No. 33 (1966).

70. McQueen, F., "Sewage Treatment for Obtaining Park Irrigation Water," *Public Works*, *64*, No. 10, pp 16-17 (1933).

72. "Manual of Septic-Tank Practice," Public Health Service Pub. No. 526, U.S. Dept. of HEW (Revised 1967).

73. Martin, B., "Sewage Reclamation at Golden Gate Park," *Sewage & Industrial Wastes*, *23*, No. 3, pp 319-320 (1951).

74. Mather, J.R., "An Investigation of Evaporation from Irrigation Sprays," *Agricultural Engineering*, *31*, No. 7, pp 345-348 (1960).

76. Melbourne and Metropolitan Board of Works, "Waste into Wealth," Melbourne, Australia (1971).

77. Metcalf & Eddy, Inc., *Wastewater Engineering*, McGraw-Hill Book Co., New York (1972).

78. Metcalf, L., and Eddy, H.P., *American Sewerage Practice*, Vol. III, Disposal of Sewage, 3rd Ed., pp 233-251, McGraw-Hill Book Co., New York (1935).

79. Merrell, J.C., et al., "The Santee Recreation Project, Santee, California, Final Report," FWPCA, U.S. Dept. of the Interior, Cincinnati, Ohio (1967).

80. Merz, R.C., "Continued Study of Waste Water Reclamation and Utilization," Calif. State Water Pollution Control Board, Publication No. 15, Sacramento, Calif. (1956).

81. Merz, R.C., "Third Report on the Study of Waste Water Reclamation and Utilization," Calif. State Water Pollution Control Board, Publication No. 18, Sacramento, Calif. (1957).

82. Miller, R.H., "The Soil as a Biological Filter," Presented at the Symposium on Recycling Treated Municipal Wastewater and Sludge through Forest and Cropland, Pennsylvania State University, University Park, Pennsylvania (August 21-24, 1972).

83. Mitchell, G.A., "Municipal Sewage Irrigation," Engineering News-Record, 119, pp 63-66 (July 8, 1937).

84. Monson, H., "Cannery Waste Disposal by Spray Irrigation - After 10 Years," Proceedings of the 13th Industrial Waste Conference, Purdue University, Lafayette, Indiana, pp 449-455 (1958).

85. Morlock, J., et al., "Reduces Wastewater Treatment Costs 20-30%; Saves Estimated $2 Million Capital Expense," Food Processing, 34, No. 1, pp 52-53 (1973).

86. Nelson, L., "Cannery Wastes Disposal by Spray Irrigation," Wastes Engineering, 23, No. 8, pp 398-400 (1952).

87. Nesbitt, J.B., "Cost of Spray Irrigation for Wastewater Renovation," Presented at the Symposium on Recycling Treated Municipal Wastewater and Sludge through Forest and Cropland, Pennsylvania State University, University Park, Pennsylvania (August 21-24, 1972).

88. "Nutrient Removal from Cannery Wastes by Spray Irrigation of Grassland," Law, J.P. Jr., Thomas, R.E., and Myers, L.H., FWPCA, U.S. Dept. of the Interior, Program No. 16080 (November 1969).

89. Pair, C.H., edit., Sprinkler Irrigation, 3rd Ed., Sprinkler Irrigation Association, Washington, D.C. (1969).

90. Parizek, R.R., et al., "Waste Water Renovation and Conservation," Penn State Studies No. 23, University Park, Pennsylvania (1967).

91. Parker, R.P., "Disposal of Tannery Wastes," Proceedings of the 22nd Industrial Waste Conference, Part I, Purdue University, Lafayette, Indiana, pp 36-43 (1967).

92. Parsons, W.C., "Spray Irrigation of Wastes from the Manufacture of Hardboard," Proceedings of the 22nd Industrial Waste Conference, Purdue University, Lafayette, Indiana, pp 602-607 (1967).

93. Philipp, A.H., "Disposal of Insulation Board Mill Effluent by Land Irrigation," Jour. WPCF, 43, No. 8, pp 1749-1754 (1971).

94. Poon, C.P.C., "Viability of Long Storaged Airborne Bacterial Aerosols," ASCE San. Engr. Div., 94, No. SA 6, pp 1137-1146 (1968).

96. Rafter, G.W., "Sewage Irrigation," USGS Water Supply and Irrigation Paper No. 3, U.S. Dept. of the Interior, Washington, D.C. (1897).

97. Rafter, G.W., "Sewage Irrigation, Part II," USGS Water Supply and Irrigation Paper No. 22, U.S. Dept. of the Interior, Washington, D.C. (1899).

99. Reinke, E.A., "California Regulates Use of Sewage for Crop Irrigation," Wastes Engineering, 22, pp 364, 376 (1951).

100. "Renovating Secondary Sewage by Ground Water Recharge with Infiltration Basins," Bouwer, H., Rice, R.C., and Escarcega, E.D., U.S. Water Conservation Laboratory, Office of Research and Monitoring, Environmental Protection Agency, Project No. 16060 DRV (March 1972).

101. "Role of Soils and Sediment in Water Pollution Control," Part 1, Bailey, G.W., Southeast Water Laboratory, FWPCA, U.S. Dept. of the Interior (March 1968).

103. Rudolfs, W., Falk, L.L., and Ragotzkie, R.A., "Contamination of Vegetables Grown in Polluted Soil: VI. Application of Results," Sewage & Industrial Wastes, 23, pp 992-1000 (1951).

104. Sanitary Engineering Research Laboratory, "Studies in Water Reclamation," Technical Bulletin No. 13, University of California, Berkeley (July 1955).

105. Schraufnagel, F.H., "Ridge-and-Furrow Irrigation for Industrial Wastes Disposal," Jour. WPCF, 34, No. 11, pp 1117-1132 (1962).

106. Schwartz, W.A., and Bendixen, T.W., "Soil Systems for Liquid Waste Treatment and Disposal: Environmental Factors," Jour. WPCF, 42, No. 4, pp 624-630 (1970).

107. Scott, R.H., "Disposal of High Organic Content Wastes on Land," Jour. WPCF, 34, No. 9, pp 932-950 (1962).

108. Sepp, E., "Disposal of Domestic Wastewater by Hillside Sprays," ASCE Env. Engr. Div., 99, No. EE2, pp 109-121 (1973).

109. Sepp, E., "Nitrogen Cycle in Groundwater," Bureau of Sanitary Engineering, Calif. State Dept. of Public Health, Berkeley (1970).

110. Sepp, E., "Survey of Sewage Disposal by Hillside Sprays," Bureau of Sanitary Engineering, Calif. State Dept. of Public Health, Berkeley (March 1965).

111. Sepp, E., "The Use of Sewage for Irrigation--A Literature Review," Bureau of Sanitary Engineering, Calif. State Dept. of Public Health (1971).

112. Skulte, B.P., "Agricultural Values of Sewage," Sewage & Industrial Wastes, 25, No. 11, pp 1297-1303 (1953).

113. Skulte, B.P., "Irrigation with Sewage Effluents," Sewage & Industrial Wastes, 28, No. 1, pp 36-43 (1956).

115. "Soil-Plant-Water Relationships," Chapter 1 in Irrigation, Section 15 of SCS National Engineering Handbook, Soil Conservation Service, U.S. Dept. of Agriculture (March 1964).

117. Sorber, C., "Protection of Public Health," Presented at the Symposium on Land Disposal of Municipal Effluents and Sludges, Rutgers University, New Brunswick, New Jersey (March 12-13, 1973).

118. "Sprinkler Irrigation," Chapter 11 in Irrigation, Section 15 of SCS National Engineering Handbook, Soil Conservation Service, U.S. Dept. of Agriculture (July 1968).

119. "Study of Reutilization of Wastewater Recycled through Groundwater," Vol. 1, Boen, D.F., et al., Eastern Municipal Water District, Office of Research and Monitoring, Environmental Protection Agency, Project 16060 DDZ (July 1971).

120. Sullivan, D., "Wastewater for Golf Course Irrigation," Water & Sewage Works, 117, No. 5, pp 153-159 (1970).

123. Thomas, R.E., and Bendixen, T.W., "Degradation of Wastewater Organics in Soil," Jour. WPCF, 41, No. 5, Part 1, pp 808-813 (1969).

124. Thomas, R.E., and Harlin, C.C., Jr., "Experiences with Land Spreading of Municipal Effluents," Presented at the First Annual IFAS Workshop on Land Renovation of Waste Water in Florida, Tampa (June 1972).

125. Thomas, R.E., and Law, J.P., Jr., "Soil Response to Sewage Effluent Irrigation," Proceedings of the Symposium on Municipal Sewage Effluent for Irrigation, Louisiana Polytechnic Institution (July 30, 1968).

126. Thomas, R.E., Schwartz, W.A., and Bendixen, T.W., "Soil Chemical Changes and Infiltration Rate Reduction Under Sewage Spreading," Soil Science Society of America, Proceedings, 30, pp 641-646 (1966).

129. Urie, D.H., "Phosphorus and Nitrate Levels in Groundwater as Related to Irrigation of Jack Pine with Sewage Effluent," Presented at the Symposium on Recycling Treated Municipal Wastewater and Sludge through Forest and Cropland, Pennsylvania State University, University Park, Pennsylvania (August 21-24, 1972).

130. U.S. Salinity Laboratory, Diagnosis and Improvement of Saline and Alkali Soils, Agriculture Handbook No. 60, U.S. Dept. of Agriculture (1963).

131. van der Goot, H.A., "Water Reclamation Experiments at Hyperion," Sewage & Industrial Wastes, 29, No. 10, pp 1139-1144 (1957).

133. "Wastewater Management by Disposal on the Land," Corps of Engineers, U.S. Army, Special Report 171, Cold Regions Research and Engineering Laboratory, Hanover, N.H. (May 1972).

135. Water Resources Engineers, Inc., "Cannery Waste Treatment, Utilization, and Disposal," California State Water Resources Control Board, Publication No. 39 (1968).

136. Wells, D.M., "Groundwater Recharge with Treated Municipal Effluent," Proceedings of the Symposium on Municipal Sewage Effluent for Irrigation, Louisiana Polytechnic Institution (July 1968).

137. Wentink, G.R., and Etzel, J.E., "Removal of Metal Ions by Soil," Jour. WPCF, 44, No. 8, pp 1561-1574 (1972).

138. Wesner, G.M., and Baier, D.C., "Injection of Reclaimed Wastewater into Confined Aquifers," Jour. AWWA, 62, No. 3, pp 203-210 (1970).

139. Williams, T.C., "Utilization of Spray Irrigation for Wastewater Disposal in Small Residential Developments," Presented at the Symposium on Recycling Treated Municipal Wastewater and Sludge through Forest and Cropland, Pennsylvania State University, University Park, Pennsylvania (August 1972).

140. Woodley, R.A., "Spray Irrigation of Organic Chemical Wastes," Proceedings of the 23rd Industrial Waste Conference, Purdue University, Lafayette, Indiana, pp 251-261 (1968).

141. Younger, V.B., "Ecological and Physiological Implications of Greenbelt Irrigation with Reclaimed Water," Presented at the Symposium on Recycling Treated Municipal Wastewater and Sludge through Forest and Cropland, Pennsylvania State University, University Park, Pennsylvania (August 21-24, 1972).

142. Zimmerman, J.P., Irrigation, John Wiley & Sons, Inc., New York (1966).

Acknowledgment

The information in the text and bibliographic list on land application techniques are excerpted from the report "Wastewater Treatment and Reuse by Land Application" prepared by Charles E. Pound and Ronald W. Crites of Mecalf and Eddy, Inc. for the Environmental Protection Agency.

III. LAND UTILIZATION TECHNIQUES

Bibliographies

"Wastewater Treatment and Reuse by Land Application - Bibliography" prepared by Metcalf and Eddy, Inc. for the Environmental Protection Agency, May 1973.

"Bibliography - Survey of Facilities Using Land Application" prepared by the American Public Works Association for the Environmental Protection Agency, April 1973.

"Land Application of Sewage Effluents and Sludges: Selected Abstracts" being prepared by the Environmental Protection Agency, May 1974 (proposed date).

Bibliographic List

1. Acevedo-Ramos, G., et al. "Effect of Filter-Press Cake on Crop Yields and Soil Properties," Compost Science, Winter 1963, p. 34.
2. Advisory Paper No. 10, 1972. "Permissible Levels of Toxic Metals in Sewage Used on Agricultural Land." Ministry of Agriculture, Fisheries, and Food, London, England.
3. Allaway, W. H. Agronomic Controls Over the Environmental Cycling of Trace Elements. Advances in Agronomy. Vol. 20: 1968. pp. 235-274.
4. Anderson, A. "Some News Regarding the Use of Municipal Wastes Within Farming," Grundfoerbaettring, Vol. 22: 1969. pp. 42-43.
5. Anderson, M. S. "Fertilizing Characteristics of Sewage Sludge," Sewage and Industrial Wastes, Vol. 31, No. 6, pp. 678-682.

6. Berg, G. "Virus Transmission by the Water Vehicle. II. Virus Removal by Sewage Treatment Procedures," Health Library Science, Vol. 2, No. 2: 1966. p. 90.

7. Cameron, R. D. "Prediction of Settlements in Landfills Constructed From Centrifuged Digested Sewage Sludge," Water Poll. Abstracts (Gt. Britain), Vol. 44, No. 1646: Aug., 1971.

8. "Chicago Reclaiming Strip Mines With Sewage Sludge," Civil Engineering-ASCE: Sept. 1972. p. 98.

9. Coker, E. G. "Utilization of sludge in agriculture." In Sludge Treatment and Disposal - Proceedings of the Symposium on the Engineering Aspects of the Use and Reuse of Water. Institution of Public Health Engineers. Municipal Publishing Company, Ltd: 1967. 136 p.

10. "Composting Dewatered Sewage Sludge," Report on Contract with Bureau of Solid Waste Management of the Department of Health, Education and Welfare. Eimco Corp., 1969.

11. Compton, C. R., and F. R. Bowerman. "Composting Operation in L. A. County," Compost Science, Winter 1961.

12. DeTurk, E. E. "Adaptability of Sewage Sludge as a Fertilizer," Sewage Works Journal, Vol. 7, No. 4: 1935. pp. 597-610.

13. Dotson, G. K., Dean, R. B., and Stern, G. "The Cost of Dewatering and Disposing of Sludge on Land." Presented to 65th Meeting of the AIChE, New York, Nov. 26-30, 1972. To be published in "Water-1972."

14. Ewing, B. B., and Dick, R. I. "Disposal of Sludge on Land." In "Water Quality Improvement by Physical and Chemical Processes," Univ. of Texas Press, Austin: 1970. E. F. Gloyna and W. W. Eckenfelder, Jr., editors.

15. Farrell, J. B., Smith, J. E., Hathaway, S. W., and Dean, R. B. "Lime Stabilization of Chemical-Primary Sludges at 1.15 MGD." Presented to 45th Annual Conf., Water Poll. Control Federation, Atlanta, Georgia, Oct. 8-13, 1972. To be published in JWPCF.

16. Fuller, J. E., and G. W. Jourdian. "Effect of Dried Sewage Sludge on Nitrification in Soil," Sewage and Industrial Wastes, Vol. 27, No. 2. pp. 161-165.

17. Hinesly, T. D., Braids, O. C., Molina, J. A. E., Dick, R. I., Jones, R. L., Meyer, R. C., and Welch, L. Y. "Agricultural Benefits and Environmental Changes Resulting from the Use of Digested Sewage Sludge on Field Crops." Annual Report, Univ. of Illinois and City of Chicago, 1972. EPA Grant DO 1-UI-00080, unpublished.

18. Hinesly, T. D., Jones, R. L., and Ziegler, E. L. "Effects on Corn by Applications of Heated Anaerobically Digested Sludge," Compost Science, Vol. 13, No. 4: July-Aug. 1972. pp. 26-30.

19. Hinesly, Thomas D., and B. Sosewitz. "Digested Sludge Disposal on Crop Land," 41st Annual Convention, Water Pollution Control Federation, Chicago, Illinois, Sept., 1968.

20. Kenner, B. A., Dotson, G. K., and Smith, J. E., Jr. "Simultaneous Quantitation of Salmonella Species and Pseudomonas Aeroginosa," EPA-NERC-Cincinnati, internal report: 1971.

21. Lunt, H. A. "The Case for Sludge as a Soil Improver," Water and Sewage Works, Vol. 100, No. 8. pp. 295-301.

22. Le Riche, H. H. "Metal Contamination of Soil in the Woburn Market - Garden Experiment Resulting from the Application of Sewage Sludge," J. Agri. Sci. Camb., Vol. 71: 1968. pp. 205-208.

23. Liebman, H. "Hygienic Requirements for Sludge Pasteurization and Its Control in Practice," International Research Group on Refuse Disposal (IRGRD), Info. Bull. Nos. 21-31, Aug. 1964-Dec. 1967. pp. 325-330.

24. Nusbaum, I., and L. Cook, Jr. "Making Topsoil with Wet Sludge," *Wastes Engineering*, August 1960. pp. 438-440.

25. Olds, J. "The Use and Marketing of Sludge as a Soil Conditioner," *Proc. of the 8th Southern Municipal and Industrial Wastes Conference*, 1959. pp. 219-225.

26. Olds, J. "How Cities Distribute Sludge as a Soil Conditioner," *Compost Science*, Autumn 1960. pp. 26-30.

27. Peterson, J. R., C. Lue-Hing, and D. R. Zenz. "Chemical and Biological Quality of Municipal Sludge," *Symposium on Recycling Treated Municipal Waste Water and Sludge Through Forest and Croplands*. The Pennsylvania State University, University Park, Pa.: 1972.

28. Peterson, J. R., T. M. McCalla, and G. E. Smith. "Human and Animal Wastes as Fertilizers," *Fertilizer Technology and Use*, 2nd edition. Soil Science Society of America, Madison, Wisconsin: 1971.

29. Proceedings of the Conference on Land Disposal of Municipal Effluents and Sludges, Rutgers University, New Jersey, March 12 and 13, 1973. Sponsored by the U. S. Environmental Protection Agency, Region II, and the College of Agriculture and Environmental Science, Rutgers University.

30. Reeves, J. B. "Sanitary Aspects of Composted Sewage Sludge and Sawdust," *Sewage and Industrial Wastes*, Vol. 31, No. 5. pp. 557-563.

31. Routson, R. C., and R. E. Wildung. "Ultimate Disposal of Wastes to Soil," *Water-1969. Chemical Engineering Progress Symposium Series. American Institute of Chemical Engineers*, Vol. 65, No. 97: 1969. pp. 19-25.

32. Scaulon, A. J. "Utilization of Sewage Sludge for the Production of Topsoil," Sewage and Industrial Wastes, Vol. 29, No. 8. pp. 944-950.

33. Scott, R. H. "Disposal of High Organic Content Wastes on Land," JWPCF, Vol. 34, No. 9. pp. 932-950.

34. Skibniewski, L. "Chemical Problems in the Utilization of Sewage in Agriculture," Gaz. Woda. Tech. Sanitarna (Polish), Vol. 23, No. 52: February 1949.

35. "Sewage Sludge as Soil Conditioner," Editors, Water and Sewage Works, Vol. 106. Ref. No., pp. R-403-R-424.

36. "State of the Art Review on Sludge Incineration Practice," FWQA Report No. 170 70 DIV: April, 1970.

37. "Study of Municipal Sludge for Soil Improvement," Current studies on U.S.D.A. Research Center, Clean Air and Water News, No. 4: 1972. p. 427.

38. "The Agricultural Use of Sewage Sludge and Sludge Composts," Tech. Comm. No. 7, Ministry of Agriculture and Fisheries, Great Britain, Oct. 1948.

39. Troemper, A. P. "Disposal of Liquid Digested Sludge by Crop Land Irrigation." Unpublished paper of Springfield, Ill. Sanitary District: 1972.

40. Ullrich, A. H., and M. W. Smith. "Experiments in Composting Digested Sludge at Austin, Texas," Sewage and Industrial Wastes, Vol. 22, No. 4. pp. 567-570.

41. The West Hertfordshire Main Drainage Authority, General Manager's Report, 1965-1966.

42. Wiley, J. S., "Discussion of Composting of Refuse and Sewage Sludge," Compost Science, No. 8: 1967. p. 22.

IV. FLOW REDUCTION

Bibliographic List

1. American Public Works Association. Prevention and Correction of Excessive Infiltration and Inflow into Sewer Systems - A Manual of Practice. EPA Contract No. 14-12-550 (Jan. 1971).
2. American Water Works Association Committee of Water Use. Journal of the American Water Works Association: May, 1973.
3. Bailey, J. R., Benoit, R. J., Dodson, J. L., Robb, J. M., and Wallman, H. A Study of Flow Reduction and Treatment of Waste Water From Households. General Dynamics, Electric Boat Division, EPA Contract No. 14-12-428: Dec., 1969.
4. Bailey, J. R., and Cohen, S. Demonstration of Waste Flow Reduction from Households. General Dynamics, Electric Boat Division, EPA Contract No. 68-01-0041: compilation of progress reports, latest dated June, 1973.
5. Berger, Herbert F. "Evaluating Water Reclamation Against Rising Costs of Water and Effluent Treatment," Tappi: August, 1966.
6. Boland, J. J., Hanke, S. H., and Church, R. L. An Assessment of Rate-Making Policy Alternatives for the Washington Suburban Sanitary Commission. Washington Suburban Sanitary Commission (1971).
7. Bremner, R. M. "In-Place Lining of Small Sewers," Journal of the Water Pollution Control Federation, Vol. 43, No. 7: July, 1971.
8. Carcich, I. G., Farrel, R. P., and Hetling, L. J. "Pressure Sewer Demonstration Project," Journal of the Water Pollution Control Federation, Vol. 44, No. 2: February, 1972.

9. Department of Housing and Urban Development, Office of Research and Technology. "Modular Integrated Utility System (MIUS), Program Description." December 1972.

10. Eller, J., Ford, D. L., and Gloyna, E. F. "Water Reuse and Recycling in Industry," *Journal of American Water Works Association*: March, 1970.

11. Environmental Protection Agency. "Alaska Village Demonstration Projects," Report to Congress, prepared by the Office of Research and Development. July 1, 1973.

12. Environmental Protection Agency. "Guidelines for Sewer System Evaluation." Draft, September 1973.

13. Ethridge, D. E., and Seagraves, J. A. *Two Methods of Studying the Effect of Municipal Sewer Surcharges on Food Processing Wastes*. Economics Research Report No. 18, North Carolina State University: December, 1971.

14. Fristoe, C. W., Goddard, F. O., and Keig, N. G. *Applied Criteria for Municipal Water Rate Structures*. Department of Economics, College of Business Administration, University of Florida OWRR Project C-1082.

15. Gilkey and Beckman. *Water Requirements and Uses in Arizona Mineral Industry*. Bureau of Mines Information Circular 8162: 1963.

16. Gomez, Hector J. "Water Reuse at the Celulosa Y Derivades, S. A. Plants," *Proceedings, 23rd Industrial Waste Conference*, Purdue University: 1968.

17. Guarneri, C. A., Reed, R., and Reman, R. E. *Study of Water Recovery and Solid Waste Processimg for Aerospace and Domestic Applications, Vols. 1 and 2*. Contract NAS 9-12503, Grumman Aerospace Corp.: December 1972.

18. Gysi, M. "The Effect of Price on Long Run Water Supply Benefits and Costs," Water Resources Bulletin, *Journal of the American Water Resources* Association, Vol. 7, No. 3: June, 1971.

19. Hirshleifer, J., De Haven, J. C., and Milliman, J. W. *Water Supply: Economics, Technology and Policy*. University of Chicago Press: 1960.

20. Howe, C. W., and Linaweaver, F. P., Jr. "The Impact of Price on Residential Water Demand and Its Relation to System Design and Price Structure," *Water Resources Research*, Vol. 3, No. 1: First Quarter, 1967.

21. Howe, C. W., Russell, C. S., Young, R. A., and Vaughan, W. J. *Future Water Demands: The Impacts of Technological Change, Public Policies, and Changing Market Conditions on the Water Use Patterns of Selected Sectors of the United States Economy: 1970-1990*. Resources for the Future, Inc., prepared for the National Water Commission: March, 1971.

22. Mann, P. C. *Water Service Prices: A Principal Component and Regression Analysis of Determinants*. Regional Research Institute, West Virginia University, prepared for Office of Water Resources Research, project number C-2012: July, 1972.

23. Ridge, R. *The Impact of Public Water Utility Pricing Policy on Industrial Demand and Reuse*. General Electric Re-Entry and Environmental Systems Division, OWRR Contract 14-31-001-3697: November, 1972.

24. Russell, Cliffords S. *Industrial Water Use*, Section 2, Report to the National Water Commission, Resources for the Future Inc., Washington, D.C.

25. Schmidt, O. J. "Pollution Control in Sewers," *Journal of the Water* Pollution Control Federation, Vol. 44, No. 7: July, 1972.

26. Shumacher, E. A. *Study of Water Recovery and Solid Waste Processing for Aerospace and Domestic Applications*. 2 vols., Contract NAS 9-12504, Martin Marietta: January, 1973.

27. Washington Suburban Sanitary Commission, "Final and Comprehensive Report, Cabin John Drainage Basin, Water-Saving Customer Education and Appliance Test Program." February, 1973.

V. PONDS

Bibliographic List

1. Benjes, Henry, Jr. "Theory of Aerated Lagoons." Presented at the Second International Symposium for Waste Treatment Lagoons, Kansas City, Missouri, June 23-25, 1970.
2. Boyko, B. I., and J. W. G. Rupke. "Aerated Lagoons in Ontario--Design and Performance Considerations." Presented at the Second International Symposium for Waste Treatment Lagoons, Kansas City, Missouri, June 23-25, 1970.
3. Brown and Caldwell Consulting Engineers. "Upgrading Lagoons." Prepared for the Technology Transfer Design Seminar, Denver, Colorado, October 31-November 1, 1972.
4. Burns, G. E., R. M. Girling, A. R. Pick, and D. W. Vanes. "A Comparative Study of Aerated Lagoon Treatment of Municipal Wastewaters." Presented at the Second International Symposium for Waste Treatment Lagoons, Kansas City, Missouri, June 23-25, 1970.
5. Canham, R. A. "Stabilization Ponds in the Canning Industry." In Advances in Water Quality Improvement, Univ. of Texas Press, Austin, Texas: 1968. p. 464.
6. Clark, Sidney E., Harold J. Coutts, and Robert Jackson. "Alaska Sewage Lagoons." Presented at the Second International Symposium for Waste Treatment Lagoons, Kansas City, Missouri, June 23-25, 1970.
7. Coerver, J. R. "Louisiana Practice and Experience with Anaerobic-Aerobic Pond System for Treating Packinghouse Wastes," JWPCF, Vol. 36: 1964. p. 931.

8. Cooper, Robert C., William J. Oswald, and Joseph C. Bronson. "Treatment of Organic Industrial Wastes by Lagooning," Proc. 20th Ind. Waste Conf., Purdue Univ., Ext. Ser. 118, 357, 1965.

9. Day, John W., Jr., Charles M. Weiss, and H. T. Odum. "Carbon Budget and Total Productivity of an Estuarine Oxidation Pond Receiving Secondary Sewage Effluent." Presented at the Second International Symposium for Waste Treatment Lagoons, Kansas City, Missouri, June 23-25, 1970.

10. Dornbush, James N. "State of the Art--Anaerobic Lagoons." Presented at the Second International Symposium for Waste Treatment Lagoons, Kansas City, Missouri, June 23-25, 1970.

11. Fisher, Charles P., W. R. Dryman, and G. L. Van Fleet. "Waste Stabilization Pond Practices in Canada." In Advances in Water Quality Improvement, Univ. of Texas Press, Austin, Texas: 1968. p. 435.

12. Fitzgerald, George P., and Gerard A. Rohlich. "An Evaluation of Stabilization Pond Literature," Sewage Works, p. 1213.

13. Gloyna, E. F. and J. Aguirre. "New Experimental Pond Data." Presented at the Second International Symposium for Waste Treatment Lagoons, Kansas City, Missouri, June 23-25, 1970.

14. Goodnow, Weston E. "Current Design Criteria for Aerated Lagoons." Presented at the Second International Symposium for Waste Treatment Lagoons, Kansas City, Missouri, June 23-25, 1970.

15. Hemens, J., and G. J. Stander. "Nutrient Removal from Sewage Effluents by Algal Activity." Presented at the Fourth International Conference on Water Pollution Research, Prague, Czechoslovakia, September 2-6, 1968.

16. Ham, Leonard W. "Chlorination of Waste Pond Effluents." Presented at the Second International Symposium for Waste Treatment Lagoons, Kansas City, Missouri, June 23-25, 1970.

17. Howe, David O., A. P. Miller, and J. E. Etzell. "Anaerobic Lagooning--A New Approach to Treatment of Industrial Wastes," Proceedings of the 18th Indiana Waste Conference. Purdue University Extension Series, 115, 233: 1963.

18. Little, John A., Bobby J. Carroll, and Ralph E. Gentry. "Bacteria Removal in Oxidation Ponds." Presented at the Second International Symposium for Waste Treatment Lagoons, Kansas City, Missouri, June 23-25, 1970.

19. Lyman, Edwin D., Melville W. Gray, and John H. Bailey. "A Field Study of the Performance of Waste Stabilization Ponds Serving Small Towns." Presented at the Second International Symposium for Waste Treatment Lagoons, Kansas City, Missouri, June 23-25, 1970.

20. Loehr, R. C. "Anaerobic Lagoons--Considerations in Design and Application," American Soc. Agric. Engrs. Trans., Vol. 11, No. 3: May-June, 1968. p. 320.

21. Mackenthun, Kenneth M., and Clarence D. McNabb. "Stabilization Pond Studies in Wisconsin," Journal of the Water Pollution Control Federation. p. 1234.

22. Marais, G. v. R., and M. J. Capri. "A Simplified Kinetic Theory for Aerated Lagoons." Presented at the Second International Symposium for Waste Treatment Lagoons, Kansas City, Missouri, June 23-25, 1970.

23. McCarty, P. L. "Anaerobic Waste Treatment Fundamentals," Public Works, Vol. 93, No. 9, 10, 11, and 12: September-December, 1964.

24. McKinney, Ross E. "State of the Art--Aerated Lagoons." Presented at the Second International Symposium for Waste Treatment Lagoons, Kansas City, Missouri, June 23-25, 1970.

25. Mees, Quentin M., and J. R. Hensley. *Survival of Pathogens in Sewage Stabilization Ponds*. Final report, NIH Research Grant E-3436.

26. Middleton, Francis M., and Robert L. Bunch. "Challenge for Wastewater Lagoons." Presented at the Second International Symposium for Waste Treatment Lagoons, Kansas City, Missouri, June 23-25, 1970.

27. Myers, Earl A., and T. C. Williams. "A Decade of Stabilization Lagoons in Michigan with Irrigation as Ultimate Disposal of Effluent." Presented at the Second International Symposium for Waste Treatment Lagoons, Kansas City, Missouri, June 23-25, 1970.

28. Oregon State University Dept. of Civil Engineering. *Final Report: Waste Water Lagoon Criteria for Maritime Climates*. Engineering Experiment Station, Corvallis, Oregon.

29. Pohl, Edward F. "A Rational Approach to the Design of Aerated Lagoons." Presented at the Second International Symposium for Waste Treatment Lagoons, Kansas City, Missouri, June 23-25, 1970.

30. *Proceedings of the Second International Symposium for Waste Treatment Lagoons*, FWQA, Kansas City, Missouri.

31. Richmond, Maurice S. "Quality Performance of Waste Stabilization Lagoons in Michigan." Presented at the Second International Symposium for Waste Treatment Lagoons, Kansas City, Missouri, June 23-25, 1970.

32. Roesler, Joseph F., and Herbert C. Preul. "Mathematical Simulation of Waste Stabilization Ponds." Presented at the Second International Symposium for Waste Treatment Lagoons, Kansas City, Missouri, June 23-25, 1970.

33. Schurr, Karl. "A Comparison of an Efficient Lagoon System with Other Means of Sewage Disposal in Small Towns." Presented at the Second International Symposium for Waste Treatment Lagoons, Kansas City, Missouri, June 23-25, 1970.

34. Shindala, Adnan. Evaluation of Three Waste Stabilization Ponds in Series. Engineering and Industrial Research Station, Mississippi State University: August, 1971.

35. Slanetz, L. W., Clara H. Bartley, T. G. Metcalf, and R. Nesman. "Survival of Enteric Bacteria and Viruses in Municipal Sewage Lagoons." Presented at the Second International Symposium for Waste Treatment Lagoons, Kansas City, Missouri, June 23-25, 1970.

36. Sudweeks, Calvin K. "Development of Lagoon Design Standards in Utah." Presented at the Second International Symposium for Waste Treatment Lagoons, Kansas City, Missouri, June 23-25, 1970.

37. Ullrich, A. H. "Use of Wastewater Stabilization Ponds in Two Different Systems," Journal of the Water Pollution Control Federation. p. 965.

38. Vennes, John W. "State of the Art--Oxidation Ponds." Presented at the Second International Symposium for Waste Treatment Lagoons, Kansas City, Missouri, June 23-25, 1970.

VI. ACTIVATED SLUDGE

Bibliographic List

1. Agnew, W. A. "A Mathematical Model of a Final Clarifier for the Activated Sludge Process," FWQA Department of the Interior, No. 14-12-194: March, 1970.
2. Albertsson, J. G., J. R. McWhirter, E. K. Robinson, and No. P. Walhdieck. "Investigation of the Use of High Purity Oxygen Aeration in Conventional Activated Sludge Process," FWQA Department of the Interior Program No. 17050 DNW, Contract No. 14-12-465: May, 1970.
3. Barth, E. F., M. Mulbarger, B. V. Salotto, and M. B. Ettinger. "Removal of Nitrogen by Municipal Wastewater Treatment Plants." Presented at the 38th Annual Conference of the Water Pollution Control Federation, Atlantic City, New Jersey, Oct. 10-14, 1965.
4. Bechtel Incorporated. *A Guide to the Selection of Cost-Effective Wastewater Treatment Systems*. U.S. Environmental Protection Agency: May, 1973.
5. Bishop, D., T. O'Farrell, J. Stamberg, and J. Porter. "Advanced Waste Treatment Systems at the Environmental Protection Agency, District of Columbia Plant," *A.W.T.R.L.*, E.P.A.: March, 1971.
6. Delwiche, C. C., and M. S. Finstein. "Carbon and Energy Sources for the Nitrifying Autotroph Nitrobacter," *J. of Bact.*, Vol. 90, No. 102: 1965.
7. Dick, Richard I. "Gravity Thickening," Summer Institute in Water Pollution Control - Biological Treatment. Manhattan College, New York: 1969.
8. Dick, Richard I., and Benjamin B. Ewing. "Evaluation of Activated Sludge Thickening Theories," *Journal Sanitary Eng. Div. ASCE*, SA4: 1967. p. 9.

9. Dick, Richard I., and Benjamin B. Ewing. Closure "Evaluation of Activated Sludge Thickening Theories," Journal Sanitary Eng. Div. ASCE, Vol. 95, No. SA2: April, 1969. p. 333.

10. Dick, Richard I., and P. A. Vesilind. "The Sludge Volume Index - What Is It?," Journal Water Pollution Control Federation, Vol. 41, No. 7: July, 1969. p. 1285.

11. Downing, A. L., T. G. Tomlinson, and G. A. Truesdale. "Effects of Inhibitors on Nitrification in the Activated Sludge Process," Journal and Proceedings of the Inst. Sew. Purif., Part 6: 1964.

12. Duncan, J. W. K., and K. Kawata. Discussion of "Evaluation of Sludge Thickening Theories," Journal Sanitary Eng. Div., ASCE, Vol. 94, No. SA2: April. 1968. p. 431.

13. Dye, E. O. "Solids Control Problems in Activated Sludge," Sewage and Industrial Wastes, Vol. 30, No. 11: 1958. p. 1350.

14. Eckenfelder, W. W., and R. F. Weston. "Kinetics of Biological Oxidation," Biological Treatment of Sewage and Industrial Wastes. Reinhold Publishing Corp., New York: 1956.

15. Eckenfelder, W. W., Jr. "Extended aeration - a summary." Paper presented at the Annual Meeting of the ASCE, New York, N.Y.: October 17, 1961. 4 pp.

16. Eckhoff, D. W., and D. Jenkins. "Transient Loading Effects in the Activated Sludge Process," in Advances in Water Pollution Research, Munich: Journal WPCF, Vol. 2: 1967.

17. Engel, M. S., and M. Alexander. "Growth and Autotrophic Metabolism of Nitrosomonas Europaea," Jour. Bacteriol., Vol. 76: 1958. p. 217.

18. Garrison, Walter E., and Carl A. Nagel. "Operation of the Whittier Narrows Activated Sludge Plant," Water and Sewage Works, Reference No. R-189: November, 1965.

19. Grieves. R. B., W. F. Milbury, and W. O. Pipes. "The Effect of Short Circuiting Upon the Completely-Mixed Activated Sludge Process," International Journal Air and Water Pollution, Vol. 8: 1964. pp. 199-214.

20. Hais, Stamberg, J., and D. Bishop. "Alum Addition to Activated Sludge with Tertiary Solids Removal," A.W.T.R.L., E.P.A., Preliminary Report: March, 1971.

21. Heukelekian, H. "The Influence of Nitrifying Flora, Oxygen and Ammonia Supply on the Nitrification of Sewage," Sewage Works Journal, Vol. 14: 1942. pp. 964-979.

22. Heukelekian, H. "The Relationship Between Accumulation Biochemical and Biological Characteristics of Film and Purification Capacity of a Biofilter and a Standard Filter - III. Nitrification and Nitrifying Capacity of the Film," Sewage Wks. J., Vol. 17: 1945. p. 516.

23. Heukelekian, H., H. E. Orford, and R. Manganelli. "Factors Affecting the Quantity of Sludge Production in the Activated Sludge Process," Sewage and Industrial Wastes, Vol. 23: 1951. pp. 945-957.

24. Hydroscience, Inc. Advanced Waste Treatment Studies for Nitrogen and Phosphorus Removal. Written for Baldwin and Cornelius Company: March, 1971.

25. Hydroscience, Inc. Nitrification in the Activated Sludge Process, City of Flint, Michigan. Prepared for Consoer, Townsend and Associates, Chicago, Illinois: July, 1971.

26. Ingersoll, A. C., J. E. McKee, and N. H. Brooks. "Fundamental Concepts of Rectangular Settling Tanks," *Proc. Amer. Soc. Civil Eng.*, Vol. 81, No. 590: January, 1955.

27. Jenkins, D., and W. E. Garrison. "Control of Activated Sludge by Mean Cell Residence Time," *Jour. Water Poll. Control Fed.*, Vol. 40, 1968. p. 1905.

27. Jenkins, S. H. "Nitrification," *Wat. Pollut. Control 1969*. p. 610.

28. Jensen, H. L. "Effect of Organic Compounds on Nitrosomonas," *Nature*, Vol. 165: 1950. p. 974.

29. Jones, R., R. Briggs, J. G. Carr, and A. H. Potten. *Automatic Control of Aeration in a Fully Nitrifying Activated Sludge Plant*. Paper presented at the Institute of Public Health Engineers, Land, March 6, 1969.

30. Katz, W. J., and A. Geinopolos. Discussion of "Flow Patterns in a Rectangular Sewage Sedimentation Tank," *Advances in Water Pollution Research*, Proceedings 1st International Conference, London, Pergamon Press, Oxford: 1964.

31. Keefer, C. E. "Relationship of Sludge Density Index to the Activated Sludge Process," *Journal Water Pollution Control Federation*, Vol. 35, No. 9: 1963. p. 1166.

32. Krone, Ray B. Discussion of "Evaluation of Sludge Thickening Theories," *Journal Sanitary Eng. Div., ASCE*, Vol. 94, No. SA3: June, 1968. p. 554.

33. Lawrence, A. L., and P. L. McCarty. "Unified Basis for Biological Treatment Design and Operation," *Journ. of Amer. Soc. of Civil Eng.*, S.E.D., 96, 757-778, 1970.

34. Lesperance, Theodore W. "A Generalized Approach to Activated Sludge," *Water and Wastes Engineering*: May, 1965.

35. McCarty, P. L. *Nitrification-Denitrification by Biological Treatment*. University of Massachusetts, W.R.R.C. Correspondents Conf. on Denitrification of Municipal Wastes: March, 1973.

36. McCarty, P. L. "Stoichiometry of Biological Reactions." Presented at the International Conference Toward a Unified Concept of Biological Waste Treatment Design, Atlanta, Georgia: October 6, 1972.

37. McKinney, Ross E. "Fundamental Approach to the Activated Sludge Process - II. A Proposed Theory of Floc Formation," *Sewage and Industrial Wastes*, Vol. 24, No. 3: 1952. p. 280

38. McKinney, R. E., J. M. Symons, W. G. Shifrin, and M. Vezina. "Design and Operation of a Complete Mixing Activated Sludge System," *Sew. and Ind. Wastes*, Vol. 30, No. 3: March, 1958. p. 287.

39. McKinney, R. E. "Mathematics of Complete-Mixing Activated Sludge," *Jour. San. Eng. Div., Proc. Amer. Soc. Civil Engr.*, Vol. 88, SA3: 1962. p. 87.

40. Metcalf and Eddy, Inc. *Nitrification and Denitrification Facilities*. E.P.A. Technology Transfer Program, Chicago, Illinois, Design Seminar, November 28-30, 1972.

41. Morris, Grover L., Lowell Van Den Berg, Gordon L. Culp, Jack R. Geckler, and Ralph Porges. *Extended-Aeration Plants and Intermittent Watercourses*. U.S. Department of Health, Education, and Welfare, Public Health Service, Division of Water Supply and Pollution Control, Cincinnati, Ohio: July, 1963.

42. Mulbarger, M. C. "Nitrification and Denitrification in Activated Sludge Systems," *J.W.P.C.F.*, Vol. 43: 1971. pp. 2059-2070.

43. Mulbarger, M. C. "The Three Sludge System for Nitrogen and Phosphorus Removal," *A.W.T.R.L.*, E.P.S.: April, 1972.

44. Okun, D. A., and W. R. Lynn. "Preliminary Investigation into the Effect of Oxygen Tension on Biological Sewage Treatment," in *Biological Treatment of Sewage and Industrial Wastes: Vol. I, Aerobic Oxidation*. Reinhold Publishing Corp., New York: 1956.

45. Reed, S. C., and R. S. Murphy. "Low Temperature Activated Sludge Settling," *Journal Sanitary Engineering Division, ASCE*, No. SA4: August, 1969.

46. Rimer, A. E., and R. L. Woodward. "Two Stage Activated Sludge Pilot Operations at Fitchburg, Massachusetts," *J.W.P.C.F.*, No. 44: 1972. pp. 101-116.

47. Sawyer, C. N. "Final Clarifiers and Clarifier Mechanisms," in *Biological Treatment of Sewage and Industrial Wastes*. Reinhold Publishing Corp., New York: 1957.

48. Sawyer, C. N. "Milestones in the Development of the Activated Sludge Process," *Journal Water Pollution Control Federation*, Vol. 37, No. 2: February, 1965.

49. Smith, Robert. *A Compilation of Cost Information for Conventional and Advanced Wastewater Treatment Plants and Processes*. U.S. Department of the Interior, Federal Water Pollution Control Administration, Advanced Waste Treatment Branch, Division of Research; Cincinnati Water Research Laboratory, Cincinnati, Ohio: December, 1967.

50. Stamberg, John B., Dolloff F. Bishop, Alan B. Hais, and Stephen M. Bennett. *System Alternatives in Oxygen Activated Sludge*. U.S. Environmental Protection Agency, Office of Research and Monitoring, National Environmental Research Center, Cincinnati, Ohio.

51. Stamberg, John B., Dolloff F. Bishop, and Gordon Kumke. Activated Sludge Treatment With Oxygen. Environmental Protection Agency, Advanced Waste Treatment Research Laboratory, Robert A. Taft Water Research Center, Cincinnati, Ohio: March, 1971.

52. Stankewich, Michael J., Jr. "Biological Nitrification With the High Purity Oxygenation Process." Presented at the 27th Annual Industrial Waste Conference, Purdue University, Lafayette, Indiana: May 2-4, 1972.

53. Wilcox, E. "Operating Experience and Design Criteria for 'Unox' Wastewater Treatment Systems," EPA Technology Transfer Seminar, New York, New York: February 29-March 2, 1972.

54. Wild, H., C. Sawyer, and T. McMahon. "Factors Affecting Nitrification Kinetics," J.W.P.C.F., Vol. 43: 1971. pp. 1845-1854.

VII. TRICKLING FILTERS

Bibliographies

Dow Chemical Co. A Literature Search and Critical Analysis of Biological Trickling Filter Studies--Volume II. United States Environmental Protection Agency: December, 1971.

Bibliographic List

1. Balakrishnan, S., and W. W. Eckenfelder, Jr. "Nitrogen Relationships in Biological Treatment Process--II. Nitrification in Trickling Filters," Water Resources, Vol. 3: 1969. p. 167.
2. Benzie, Wallace J., Herbert O. Larkin, and Allan F. Moore. "Effects of Climatic and Loading Factors on Trickling Filter Performance." Presented at 35th Meeting of WPCF: October 7-11, 1962.
3. Bloodgood, D. E., G. H. Teletzke, and F. G. Pohland. "Fundamental Hydraulic Principles of Trickling Filters," Sewage and Industrial Wastes, Vol. 31, No. 3: March, 1959. p. 243.
4. Brown, James C., Linda W. Little, Donald E. Francisco, and James C. Lamb. Methods for Improvement of Trickling Filter Plant Performance. Contract 14-12-505, Project 11010 DGA, Program Element 1B2043, Office of Research and Development, U.S. Environmental Protection Agency, Washington, D.C.
5. Burgess, F. J., C. M. Gilmour, F. Merryfield, and J. K. Carswell. "Evaluation Criteria for Deep Trickling Filters." Presented at 33rd Meeting of WPCF, Philadelphia: October 2-6, 1960.
6. Cameron, W. M., and A. R. Jamieson. "Further Operation of an Enclosed Filter at Dalmarnock Sewage Works," Jour. and Proc. Inst. Sew. Purif., part 4: 1950. p. 417.

7. Duddles, Glenn A., and Steven E. Richardson. *Application of Plastic Media Trickling Filters for Biological Nitrification Systems*. Contract 14-12-900, Project 17010 SJF, U.S. Environmental Protection Agency, Washington, D.C.

8. Eckenfelder, W. W., and S. W. Hood. "The Role of Ammonia Nitrogen in Sewage Treatment," *Water and Sewage Works*, Vol. 97: 1950, pp. 246-250. *Pollution Abstracts*: 1951, p. 1027.

9. Fair, G. M., R. E. Fuhrman, C. C. Ruchhoft, H. A. Thomas, and F. W. Mohlman. "Sewage Treatment at Military Installations--Summary and Conclusions," *Sewage Works Jour.*, Vol. 20, No. 1: January, 1948. p. 52.

10. Fairall, J. M. "Correlation of Trickling Filter Data," *Sewage and Industrial Wastes*, Vol. 28, No. 9: September, 1956. p. 1069.

11. Franzmathes, Joseph R. "Operational Costs of Trickling Filters in the Southeast," *J.W.P.C.F.*, Vol. 4, No. 5: May, 1969. p. 814.

12. Grantham, G. R., E. B. Phelphs, W. T. Calaway, and D. L. Emerson. "Progress Report on Trickling Filter Studies," *Sewage Wks. J.*, Vol. 22, No. 7: 1950. p. 867.

13. Heukelekian, H. "The Relationship Between Accumulation Biochemical and Biological Characteristics of Film and Purification Capacity of a Biofilter and a Standard Filter--III. Nitrification and Nitrifying Capacity of the Film," *Sewage Wks. J.*, Vol. 17: 1945. p. 516.

14. Hanumanulu, V. "Effect of Recirculation on Deep Trickling Filter Performance," *J.W.P.C.F.*, Vol. 41, No. 10. p. 1803.

15. Hazen and Sawyer. "*Upgrading Existing Wastewater Treatment Plants: Case Histories*." Presented at Environmental Protection Agency Technology Transfer Program Design Seminar, Pittsburgh, Pa: August 29-31, 1972.

16. Moore, W. A., R. S. Smith, and C. C. Runchhoft. "Efficiency Study of a Recirculating Sewage Filter at Centralia, Mo.," *Sew. and Ind. Wastes*, Vol. 22: 1950. p. 184.

17. NRC Sub-Committee on Sewage Treatment. "Sewage Treatment at Military Installations--Summary and Conclusions," *Sewage Works Jour.*, Vol. 20, No. 1: January, 1948. p. 52.

18. Rankin, R. S. "Evaluation of the Performance of Biofiltration Plants," *Trans. Amer. Soc. Civil Engr.*, No. 120: 1955. p. 823.

19. Sack, William A., and Stephen A. Phillips. Evaluation of the Bio-Disc Treatment Process for Summer Camp Application. Project S-800707, Program Element 1B2043, Office of Research and Development, U.S. Environmental Protection Agency, Washington, D.C.

20. Schroepfer, G. J., M. B. Al-Hakim, H. F. Seidel, and N. R. Ziemke. "Temperature Effects on Trickling Filters," *Sewage Works Jour.*, Vol. 24, No. 6: June, 1952. p. 705.

21. Shriver, Larry E., and James C. Young. "Oxygen Demand Index as a Rapid Estimate of Biochemical Oxygen Demand," *J.W.P.C.F.*, Vol. 44, No. 11: November, 1972. p. 2146.

22. Sinkoff, M. D., R. Porges, and J. H. McDermott. "Mean Residence Time of a Liquid in a Trickling Filter," *Jour. San. Engr. Div., Amer. Soc. Civil Engr.*, Vol. 85, SA6: November, 1959. p. 51.

23. Sorrels, J. H., and P. J. A. Zeller. "Two-Stage Trickling Filter Performance," *Sewage Wks. J.*, Vol. 28, No. 8: 1956. p. 934.

24. Thoman, John R., and Kenneth H. Jenkins. "Use of Final Settling Tanks With Standard-Rate Trickling Filters," *Sewage Works Jour.*, Vol. 31, No. 5. p. 842.

25. Velz, C. J. "A Basic Law for the Performance of Biological Filters," Sewage Works Jour., Vol. 20, No. 4: July, 1948. p. 607.

VIII. PHYSICAL-CHEMICAL TREATMENT

Bibliographic List

1. Battelle-Northwest, Richland Washington, and South Lake Tahoe Public Utility District, South Lake Tahoe, California. *Wastewater Ammonia Removal by Ion Exchange*, U.S. Environmental Protection Agency, Project 17010 ECZ 02/71.
2. Bishop, D. F. "*Advanced Waste Treatment Research at the FWPCA-DC Pilot Plant*." Presented at the FWPCA Technical Workshop, Fredericksburg, Va.: May 13, 1969.
3. Bishop, D. F., et al. "Studies on Activated Carbon Treatment," *Jour. Water Poll. Control Fed.*, Vol. 39: 1967. p. 188.
4. Bishop, Dolloff F., Thomas P. O'Farrell, and John B. Stamberg. "Physical-Chemical Treatment of Municipal Wastewater," *J.W.P.C.F.*, Vol. 44, No. 3: March, 1972.
5. Black and Veatch, Consulting Engineers. *Process Design Manual for Phosphorous Removal*. U.S. Environmental Protection Agency Technology Transfer Program: October, 1971.
6. Burns and Roe Inc. *Process Design Manual for Suspended Solids Removal*. U.S. Environmental Protection Agency Technology Transfer Program: October, 1971.
7. Cassel, Alan F., Thomas A. Pressley, Walter W. Schuk, and Dolloff F. Bishop. *Physical-Chemical Nitrogen Removal From Municipal Wastewater*. U.S. Environmental Protection Agency, Advanced Waste Treatment Research Laboratory, Robert A. Taft Water Research Center, Cincinnati, Ohio: March, 1971.

8. CH$_2$M/Hill and Associates. *Regional Water Reclamation Plan, Upper Occoquan Sewage Authority*. January, 1971.

9. CH$_2$M/Hill and Associates. *Wastewater Treatment Study, Montgomery County, Maryland, Volumes 1 and 11*. Prepared for Montgomery County, Maryland.

10. Culp, Gordon L. "*Physical-Chemical Treatment Plant Design*." Presented at Environmental Protection Agency Technology Transfer Seminar, Pittsburgh, Pa.: August, 1972.

11. Culp, G., and A. Slechta. "*Phosphate and Nitrogen Removal at South Tahoe Public Utility District Water Reclamation Plant*." Presented at the 39th Annual Conference WPCF Meeting, Kansas City, Mo.: September, 1966.

12. Engineering Science, Inc. "*Design Report for Nitrogen and Phosphorus Removal for Parkway Sewage Treatment Plant*." Prepared for the Washington Suburban Sanitary Commission: March, 1970.

13. Engineering Science, Inc. "*Regional Wastewater Management and Reclamation for Santa Barbara*." Prepared for the City of Santa Barbara, California: August, 1971.

14. English, J. N., et al. "*Removals of Organics from Wastewater by Activated Carbon*." Presented at the 67th National Meeting of the AIChE, Atlanta: February, 1970.

15. Hager, D. G., and D. B. Reilly. "Clarification-Adsorption in the Treatment of Municipal and Industrial Wastewaters," *Jour. Water Poll. Control Fed.*, Vol. 42: 1970. p. 794.

16. Joyce, R. S., J. B. Allen, and V. A. Sukenik. "Treatment of Municipal Wastewater by Packed Activated Carbon Beds," *Jour. Water Poll. Control Fed.*, Vol. 38: 1966. p. 813.

17. Joyce, R. S., and V. A. Sukenik. Waste and Water--Sewage Treatment Project No. 4-1007-02. Report No. 1. Pittsburgh Activated Carbon Company, a subsidiary of Calgon Corporation: May 15, 1967.

18. Koon, John H., and Warren J. Kaufman. Optimization of Ammonia Removal by Ion Exchange Using Clinoptilolite. For the Water Quality Office, Environmental Protection Agency Grant No. 17080 DAR.: Sept., 1971.

19. Molof, A. H., and M. M. Zuckerman. "High Quality Reuse Water from a Newly Developed Chemical-Physical Treatment Process." Presented at the 5th International Water Pollution Research Conference, San Francisco: July, 1970.

20. O'Farrell, T. P., F. P. Frauson, A. F. Cassel, and D. F. Bishop. "Nitrogen Removal by Ammonia Stripping." Presented at the 160th National ACS Meeting, Chicago: September, 1970.

21. O'Farrell, T. P., J. B. Stamberg, and D. F. Bishop. "Carbon Adsorption of Lime Clarified Raw, Primary, and Secondary Wastewaters." Presented at the 68th Annual Meeting of AIChE, Houston: March, 1971.

22. Parkhurst, J. D., F. D. Dryden, G. N. McDermott, and J. English. "Pomona Activated Carbon Pilot Plant," Jour. WPCF, Vol. 39, No. 10:R70, Part 2: 1967.

23. Pressley, T. A., D. F. Bishop, and S. G. Roan. "Nitrogen Removal by Breakpoint Chlorination." Presented at the 160th National ACS Meeting, Chicago: September, 1970.

24. Rizzo, J. L. "Adsorption/Filtration: A New Unit Process for the Treatment of Industrial Wastewaters." Presented at the 63rd Annual AIChE Meeting, Chicago, Illinois: November 29-December 3, 1970.

25. Rizzo, J. L., and R. E. Schade. "Secondary Treatment With Granular Activated Carbon," Water and Sewage Works: August, 1969.

26. Roy F. Weston, Inc., Environmental Scientists and Engineers. Concept Engineering Report:Advanced Wastewater Treatment, Piscataway Treatment Plant, Washington Suburban Sanitary Commission: April, 1972.

27. Roy F. Weston, Inc.; Environmental Scientists and Engineers. Process Design Manual for Upgrading Existing Wastewater Treatment Plant. Environmental Protection Agency Technology Transfer: October, 1971.

28. Smith, Clinton E., and Robert L. Chapman. Recovery of Coagulant, Nitrogen Removal and Carbon Regeneration in Wastewater Reclamation. Final Report of Project Operations, Department of Interior, Federal Water Pollution Control Administration Grant WPD-85: June, 1967.

29. Stamberg, J. B., D. F. Bishop, H. P. Warner, and S. H. Griggs. "Lime Precipitation in Municipal Wastewaters." Presented at the 62nd Annual Meeting of AIChE: November, 1969.

30. Stander, G. J., and L. R. J. Van Vuuren. "The Reclamation of Potable Water from Wastewater," Jour. Water Poll. Control Fed., Vol. 41: 1969. p. 355.

31. Swindell-Dressler Company. Process Design Manual for Carbon Adsorption. U.S. Environmental Protection Agency Technology Transfer: October, 1971.

32. Villers, R. V., E. L. Berg, C. A. Brunner, and A. N. Masse. "Treatment of Primary Effluent by Lime Clarification and Granular Carbon." Presented at the 47th Annual Meeting of ACS, Toronto: May, 1970.

33. Water Pollution Control Federation. Sewage Treatment Plant Design, WPCF Manual of Practice No. 8. Washington, D.C.: 1959 (Fifth Printing: 1972).

34. Weber, W. J., C. B. Hopkins, and R. Bloom, Jr. "Physiochemical Treatment of Wastewater," Journal WPCF: January, 1970.

IX. STORM AND COMBINED SEWERS

Bibliographic List

1. American Public Works Assn. *Combined Sewer Regulation and Management--A Manual of Practice*. Report No. 11022DMU08/70, Chicago, Illinois.
2. American Public Works Assn. *Combined Sewer Regulator Overflow Facilities*. Report No. 11022DMU07/70, Chicago, Illinois.
3. American Public Works Assn. *Problems of Combined Sewer Facilities and Overflows--1967*. Report No. 11020---12/67, Chicago, Illinois.
4. American Public Works Assn. Research Foundation. *The Swirl Concentrator as a Combined Sewer Overflow Regulator Facility*. Report No. EPA-R2-72-008 (11023 GSC), Chicago, Illinois.
5. American Society of Civil Engineers. *Combined Sewer Separation Using Pressure Sewers*. Report No. 11020EKO 10/69, Cambridge, Mass.
6. Anonymous. "Characterization, Treatment and Disposal of Urban Stormwater," Intl. Conf. on Water Pollution Research, Munich, Germany: September, 1966.
7. Banister, A. W. "*Storage and Treatment of Combined Sewage as An Alternate to Separation*." Presented at Seminar on Storm and Combined Sewer Overflows, Edison, N.J.: November, 1969.
8. Benjes, H. H., et al. "Storm-Water Overflows from Combined Sewers," *JWPCF*, Vol. 33, No. 12: 1961.
9. Black, Crow and Eidsness, Inc. *Storm and Combined Sewer Pollution Sources and Abatement, Atlanta, Ga*. Report No. 11024ELB01/71, Atlanta, Ga.
10. Bowles Engineering Corp. *Design of a Combined Sewer Fluidic Regulator*. Report No. 11020DGZ 10/69, Silver Spring, Md.

11. Burgess and Niple, Ltd. *Stream Pollution and Abatement from Combined Sewer Overflows, Bucyrus, Ohio*. Report No. 11024FKN 11/69, Columbus, Ohio.

12. Burm, R. J., "The Bacteriological Effect of Combined Sewer Overflows on the Detroit River," *JWPCF*, Vol. 39, No. 3: March, 1967. p. 410.

13. Burm, R. J., and R. D. Vaughan. "Bacteriological Comparison Between Combined and Separate Sewer Discharges in Southeastern Michigan," *JWPCF*, Vol. 38, No. 3: March, 1966. p. 400.

14. Burm, R. J., et al. "Chemical and Physical Comparison of Combined and Separate Sewer Discharges," *JWPCF*, Vol. 40, No. 1: January, 1968. p. 112.

15. Caster, A. D. "Monitoring Stormwater Overflows," *JWPCF*, Vol. 37, No. 9: September, 1965.

16. Caster, A. D., and W. J. Stein. "*Pollution From Combined Sewers, Cincinnati, Ohio*." Presented at ASCE National Water Resources Engineering Meeting, Memphis, Tennessee: January, 1970.

17. City of Chippewa Falls, Wisc. *Storage and Treatment of Combined Sewer Overflows*. Report No. EPA-R2-72-070 (11023 FIY).

18. Cochrane Division, Crane Co. *Microstraining and Disinfection of Combined Sewer Overflows*. Report No. 11023EVO 06/70, King of Prussia, Pa.

19. Detroit Metro Water Department, Detroit Sewer Monitoring and Remote Control. *Combined Sewer Overflow Abatement Technology*, U.S. Department of the Interior, Federal Water Quality Administration, Water Pollution Control Research Series, 11024, 06/70.

20. Dodson, Kinney and Lindblom. *Evaluation of Storm Standby Tanks, Columbus, Ohio*. Report No. 11020FAL 03/71, Columbus, Ohio.

21. Envirogenics Co., Div. of Aerojet-General Corp. *Urban Storm Runoff and Combined Sewer Overflow Pollution, Sacramento, California.* Report No. 11024FKM 12/71, El Monte, Calif.

22. Federal Water Quality Administration, Div. of Applied Science and Technology, Storm and Combined Sewer Pollution Control Branch. *Combined Sewer Overflow Abatement Technology*. Report No. 11024--- 06/70, Washington, D.C.

23. Field, Richard. "*Management and Control of Combined Sewer Overflows*." Presented at 44th Annual Meeting of the New York Water Pollution Control Association, New York: January, 1972.

24. Field, R., and E. Struzeski. "Management and Control of Combined Sewer Overflows," *JWPCF*, Vol. 44, No. 7: July, 1972.

25. Floyd G. Browne and Associates, Ltd. *Stormwater Overflow Study: Lima, Ohio*. Marion, Ohio: 1973.

26. FMC Corporation, Central Engineering Laboratories. *A Flushing System for Combined Sewer Cleansing*. Report No. 11020DNO 03/72, Santa Monica, Calif.

27. Glover, G. E., and G. R. Herbert. *Micro-Straining and Disinfection of Combined Sewer Overflows--Phase II*. Report No. EPA-R2-73-124 (11023 FWT), Crane Co., King of Prussia, Pa.

28. Greeley, Samuel A., and Paul E. Langdon. "Storm Water and Combined Sewage Overflows," *J. of the San Engr. Div.*, Proc. of the Am. Soc. of Civil Engin., Vol. 87: 1961. p. 57.

29. Havens and Emerson. *Feasibility of a Stabilization--Retention Basin in Lake Erie at Cleveland, Ohio*. Report No. 11020--- 05/68, Cleveland, Ohio.

30. Hayes, Seay, Mattern and Mattern. *Engineering Investigation of Sewer Overflow Problems*. Report No. 11024DMS 05/70, Roanoke, Va.

31. Hicks, W. I. "A Method of Computing Urban Runoff," *Proceedings ASCE*, Vol. 109: 1944. p. 1217.

32. Karl R. Rohrer Associates, Inc. *Underwater Storage of Combined Sewer Overflows*. Report No. 11022ECV 09/71, Akron, Ohio.

33. Koelzer, V. A., et al. "The Chicagoland Deep Tunnel Project," 41st Annual Conf. of WPCF: September 22-7, 1968.

34. Melpar Division of E Systems. *Combined Sewer Temporary Underwater Storage Facility*. Report No. 11022DPP 10/70, Falls Church, Va.

35. Metcalf and Eddy Engineers. *Storm Water Management Model, Vol. I--IV, Final Report*. Report No. 11024DOC, Palo Alto, Calif.

36. Metcalf and Eddy Engineers. *Storm Water Problems and Control in Sanitary Sewers, Oakland and Berkeley, California*. Report No. 11024EQG 03/71, Palo Alto, Calif.

37. Metropolitan Sewer Board, St. Paul. *Dispatching System for Control of Combined Sewer Losses*. Report No. 11020FAQ 03/71, St. Paul, Minnesota.

38. Mytelka, A. I., et al. *Combined Sewer Overflow Study for the Hudson River Conference*. Report No. EPA-R2-73-152 (11000---), Interstate Sanitation Commission, New York, N.Y.

39. Nebolsine, Ross, P. J. Harvey, and Chi-Yuan Fan. *High Rate Filtration of Combined Sewer Overflows*. Report No. 11023FYI 04/72, Hydrotechnic Corp., New York, N.Y.

40. Pavia, E. H., and C. J. Powell. "Chlorination and Hypochlorination of Polluted Storm Water at New Orleans," 41st Annual Conf. of WPCF: September 22-27, 1968.

41. Portland Department of Public Works, City of Portland, Oregon. *Demonstration of Rotary Screening for Combined Sewer Overflows*. Report No. 11023FDD 07/71, Portland, Ore.

42. Rex Chainbelt, Inc., Ecology Division. *Screening/Flotation Treatment of Combined Sewer Overflows*. Report No. 11020FDC 01/72, Milwaukee, Wisc.

43. Rhodes Corporation. *Dissolved-Air Flotation Treatment of Combined Sewer Overflows*. Report No. 11020FKI 01/70, Oklahoma City, Okla.

44. Roy F. Weston, Inc. *Conceptual Engineering Report--Kingman Lake Project*. Report No. 11023FIX 08/70, West Chester, Pa.

45. Roy F. Weston, Inc. *Combined Sewer Overflow Abatement Alternatives, Washington, D.C.* Report No. 11024EXF 08/70, West Chester, Pa.

46. Shuckrow, A. J. "*Physical-Chemical Treatment of Combined Sewer Overflows*." Presented at 44th Annual Meeting, New York Water Pollution Control Assn., New York: January 26-28, 1972.

47. Shuckrow, A. J., G. W. Dawson, and W. F. Bonner. *Physical-Chemical Treatment of Combined and Municipal Sewage*. Report No. EPA-R2-73-149 (11020 DSQ), PNW Laboratories, Battelle Memorial Inst., Richland, Wash.

48. Simpson, George D. "Treatment of Combined Sewer Overflows and Surface Waters at Cleveland, Ohio," 41st Annual Conf. of WPCF: September 22-27, 1968.

49. U.S. Department of Health, Education and Welfare, Public Health Service, Division of Water Supply and Pollution Control. *Pollutional Effects of Stormwater and Overflows from Combined Sewer Systems - A Preliminary Appraisal*. November, 1964.

50. University of Cincinnati. *Urban Runoff Characteristics*. Report No. 11024DQU 10/70, Cincinnati, Ohio.

X. ADVANCED WASTEWATER TREATMENT

Bibliographic List

1. Antonie, R. L. *Application of the Bio Disc Process to Treatment of Domestic Wastewater*. 43rd W.P.C.F. Conference, Boston, Massachusetts: 1970.
2. Barth, E. F., R. C. Brenner, and R. F. Lewis. "Chemical-Biological Control of Nitrogen and Phosphorus in Wastewater Effluent," *JWPCF*, Vol. 40: 1968. pp. 2040-2054.
3. Barth, E. F., M. Mulbarger, B. U. Salotto, and M. B. Ettinger. "Removal of Nitrogen by Municipal Wastewater Treatment Plants," *JWPCF*, Vol. 38: 1966. pp. 1208-1219.
4. Bishop, D. F. "*Advanced Waste Treatment at the FWPCA-DC Pilot Plant, Washington, D.C.*" Presented at a Water Pollution Control Technical Workshop on Nutrient Removal Needs, Methods, and Costs, Fredericksburg, Va.: May, 1969.
5. Bishop, Dolloff F., Thomas P. O'Farrell, and John B. Stamberg. "Physical-Chemical Treatment of Municipal Wastewater," *JWPCF*, Vol. 44, No. 3: March, 1972. p. 361.
6. Bishop, D. F., T. P. O'Farrell, J. B. Stamberg, and J. W. Porter. "*Advanced Waste Treatment Systems at the FWQA-DC Pilot Plant*." Presented at the 68th Annual Meeting of AIChE, Houston: March, 1971.
7. Bishop, D. F., et al. "Studies on Activated Carbon Treatment," *JWPCF*, Vol. 39, No. 2: February, 1967. pp. 188-203.
8. Black, S. A. *Lime Treatment for Phosphorus Removal at the Newmarket/East Guillimburg W.P.C.F*. Paper No. W3032, Ministry of the Environment, Toronto, Ontario: May, 1972.

9. Black and Veatch. *Process Design Manual for Phosphorus Removal*. E.P.A. Technology Transfer Program No. 17010: October, 1971.

10. Buswell, A. M., T. Shiota, N. Lawrence, and I. Van Meter. "Laboratory Studies on the Kinetics of the Growth of Nitrosomonas with Relation to the Nitrification Phase of the BOD Test," *Applied Microbiology*, No. 2: 1954. pp. 21-25.

11. Cassel, Alan F., Thomas A. Pressley, Walter W. Schuk, and Dolloff F. Bishop. *Physical-Chemical Nitrogen Removal from Municipal Wastewater*. Environmental Protection Agency Advanced Waste Treatment Research Laboratory, Robert A. Taft Water Research Center, Cincinnati, Ohio: March, 1971.

12. Coyen, J. M. "Nutrient Removal from Wastewater by Physical-Chemical Processes," *Proceedings, 151st A.C.S. Meeting*, Los Angeles, California: March, 1971.

13. Culp, Gordon L. *Physical-Chemical Treatment Plant Design*. Environmental Protection Agency Technology Transfer Seminar, Pittsburgh, Pennsylvania: August, 1972.

14. Culp, G., and A. Slechta. "*Phosphate and Nitrogen Removal at South Tahoe Public Utility District Water Reclamation Plant*." Presented at the 39th Annual Conference WPCF, Kansas City, Mo.: September, 1966.

15. Dawson, R. N., and K. L. Murphy. "Temperature Dependency of Biological Denitrification," *Water Research*, No. 6: 1972. p. 71.

16. Duddles, G. A., S. E. Richardson, and E. F. Barth. "*The Application of Plastic Media Trickling Filters in Biological Nitrification Systems*." Water Pollution Control Federation Conference, Atlanta, Georgia: 1972.

17. Dryden, Franklin D., Sanitation District of Los Angelos County. "Demineralization of Reclaimed Waters," J. Industrial Wastes Eng.: August/September, 1971.

18. English, J. N., et al. "Removals of Organics from Wastewater by Activated Carbon." Presented at the 67th National Meeting of the AIChE, Atlanta: February, 1970.

19. Hager, D. G., and J. L. Rizzo. Advanced Waste Treatment Design Seminar.

20. Hager, D. G., and P. B. Reilly. "Clarification-Adsorption in the Treatment of Municipal and Industrial Wastewater," JWPCF: May, 1970.

21. Haug, Roger T., and P. L. McCarty. Nitrification with the Submerged Filter. E.P.A. Technical Report No. 149: August, 1971.

22. Horstkotte, G. A., D. G. Niles, D. S. Parker, and D. H. Caldwell. "Full Scale Testing of a Water Reclamation System." Presented at 45th W.P.C.F. Conference, Atlanta, Georgia: 1972.

23. Hydroscience, Inc. Advanced Waste Treatment Studies for Nitrogen and Phosphorus Removal. Written for Baldwin and Cornelius Company: March, 1971.

24. Johnson, W. K., and G. L. Schroepfer. "Nitrogen Removal by Nitrification and Denitrification," JWPCF, Vol. 36: 1964. pp. 1015-1036.

25. Kelly, S., and S. Sanderson. "The Effect of Chlorine in Water on Enteric Viruses," American Public Health, No. 48: 1958. p. 1323.

26. Kreusch, Ed., and Ken Schmidt. "Wastewater Demineralization by Ion Exchange," Water Poll. Res. Series 17040 EEE 12/71, U.S. Environmental Protection Agency.

27. Metcalf and Eddy, Inc. *Nitrification and Denitrification Facilities*. E.P.A. Technology Transfer Program, Chicago, Illinois, Design Seminar: November 28-30, 1972.

28. McCarty, P. L. *Nitrification-Denitrification by Biological Treatment*. University of Massachusetts, W.R.R.C. Correspondents Conf. on Denitrification of Municipal Wastes: March, 1973.

29. Mulbarger, M. C. "Nitrification and Denitrification in Activated Sludge Systems," *JWPCF*, No. 43: 1971. pp. 2059-2070.

30. Mulbarger, M. C. "The Three Sludge System for Nitrogen and Phosphorus Removal," *AWTRL*, E.P.A.: April, 1972.

31. O'Farrell, T. P., D. F. Bishop, and S. M. Bennett. "*Advanced Waste Treatment at Washington, D.C.*" Presented at the 65th Annual AIChe Meeting, Cleveland, Ohio: May, 1969.

32. O'Farrell, T. P., J. B. Stamberg, and D. F. Bishop. "*Carbon Adsorption of Lime Clarified Raw, Primary, and Secondary Wastewaters*." Presented at the 68th Annual Meeting of AIChE, Houston: March, 1971.

33. Pressley, Thomas A., Dolloff F. Bishop, and Stephanie G. Roan. *Nitrogen Removal by Breakpoint Chlorination*. U.S. Department of the Interior, Federal Water Quality Administration, Advanced Waste Treatment Research Laboratory, Robert A. Taft Water Research Center, Cincinnati, Ohio: September, 1970.

34. Rimer, A. E., and R. L. Woodward. "Two Stage Activated Sludge Pilot Operations at Fitchburg, Massachusetts," *JWPCF*, No. 44: 1972. pp. 101-116.

35. Rizzo, J. L., and R. E. Schade. "Secondary Treatment with Granular Activated Carbon," *Water and Sewage Works*: August, 1969.

36. Rizzo, J. L. "Adsorption/Filtration...A New Unit Process for the Treatment of Industrial Wastewaters." Presented at the 63rd Annual AIChE Meeting, Chicago, Illinois: November 29-December 3, 1970.

37. Sanks, R. L. Report on Waste Treatment in the Merrimack River Basin by Ion Exchange. Report to North Atlantic Division, Corps of Engineers, U.S. Army: May, 1971.

38. Stamberg, J. B., D. B. Bishop, H. P. Warner, and S. H. Griggs. "Lime Precipitation in Municipal Wastewaters." Presented at 62nd Annual Meeting of AIChE: November, 1969.

39. Stensel, H. D., R. C. Loehr, and A. W. Lawrence. "Biological Kinetics of the Suspended Growth Denitrification Process," JWPCF, No. 45: 1973. pp. 244-261.

40. Tittlebaum, et al. "Ozone Disinfection of Viruses." Presented at Institute on Ozonation in Sewage Treatment, University of Wisconsin: November, 1971.

41. Torpey, W. N., H. Heukelekian, A. J. Kaplowsky, and R. Epstein. "Rotating Disks with Biological Growth Prepare Wastewater for Disposal or Reuse," JWPCF, No. 43: 1971. pp. 2181-2188.

42. Warriner, T. R. "Field Tests on Chlorination of Poliovirus in Sewage," Jour. San. Eng., ASCE, Vol. 93, SA5: 1967. p. 51.

43. Water Pollution Control Research Series. Methanol Requirements and Temperature Effects in Wastewater Denitrification. Environmental Protection Agency: August, 1970.

44. Wild, H., C. Sawyer, and T. McMahon. "Factors Affecting Nitrification Kinetics," JWPCF, No. 43: 1971. pp. 1845-1854.

45. Van Note, Robert H., Paul V. Hebert, and Ramesh M. Patel. *A Guide to the Selection of Cost-Effective Wastewater Treatment Systems*. Contract Number 68-01-0973, Municipal Wastewater Systems Division, Engineering and Design Branch, Environmental Protection Agency: February, 1974.

XI. REUSE TECHNIQUES

Bibliographic List

1. *Advanced Waste Treatment by Distillation*. Report No. AWTR-7, Public Health Service of Dept. of HEW: March, 1964.
2. *Advanced Waste Water Treatment as Practiced at South Tahoe*. EPA Report No. 170 10-ELQ-08/71, South Tahoe Public Utility Dist.: August, 1971.
3. Aerojet-General Corp., Environmental Systems Division. *Reverse Osmosis Renovation of Municipal Wastewater*. Federal Water Quality Administration Program No. 17040 EFQ, Contract No. 14-12-184, Advanced Waste Treatment Research Laboratory, Cincinnati, Ohio.
4. Ayres, R. U. "A Materials-Process-Product Model," Environ. Quality Analysis Papers from a Resources for the Future Conf., Johns Hopkins Press, Baltimore, Md.: 1972.
5. Bayley, R. W., et al. Water Pollution Research Laboratory of the Department of Environment. "Some Recent Advances in Water Reclamation," *Water Pollution Control*, Vol. 71, No. 1: 1972.
6. Bouwer, H. *Water Quality Aspects of Intermittent Systems Using Secondary Sewage Effluent*. U.S. Water Conservation Laboratory, Phoenix, Ariz., Paper No. 8: September, 1970. 19 pp.
7. Bouwer, Hermand, R. C. Rice, E. D. Escarcega, and N. S. Riggs. *Renovating Secondary Sewage by Ground-Water Recharge with Infiltration Basins*. U.S. Environmental Protection Agency, Water Pollution Control Research Series 16060DRV: 1972. 102 pp.
8. Central Contra Costa Sanitary District and Contra Costa Water District. *Municipal Wastewater Renovation Pilot/Demonstration Project*. Draft report submitted to the Environmental Protection Agency: April, 1972.

9. Chojnacki, A. "Recovery of Coagulants from the Sludge After Waste Treatment," Inst. Hydrotech. Res. Sci. Sess., Bucharest, Sect. 4: 1964. pp. 25-26. (Water Pollution Abs.: September, 1965.)

10. Chojnacki, A. "The Treatment and Use of Alum Sludge," Int. Water Supply Congress, Barcelona, Spain: October, 1966. p. Q11.

11. Cohen, Philip, and C. N. Durfor. Artificial Recharge Experiments Utilizing Renovated Sewage-Plant Effluent--A Feasibility Study at Bay Park, New York, U.S.A. In Symposium of Haifa, Artificial Recharge and Management of Aquifers: Internat. Assoc. Sci. Hydrology, Pub. No. 72: 1967. pp. 193-199.

12. Cooper, J. C., and D. G. Hager. "Water Reclamation with Granular Activated Carbon," Chemical Engineering Progress Symposium, Series No. 78, Vol. 63: 1967. p. 185.

13. Cooper, R. C., R. C. Spear, and F. L. Schaffer. Virus Survival in the Central Contra Costa County Wastewater Renovation Plant. School of Public Health, University of California, Berkeley: January, 1972.

14. Cost of Purifying Municipal Waste Water by Distillation. Report No. AWTR-6 of Public Health Service, Dept. of HEW: November, 1963.

15. Culp, Gordon, and Russell Culp. "Reclamation of Wastewater at Lake Tahoe," Public Works Magazine: February, 1966.

16. Culp, R. L., and G. L. Culp. Advanced Wastewater Treatment. Van Nostrand Reinhold Co.: 1971.

17. Culp, R. L. "Wastewater Reclamation by Tertiary Treatment," JWPCF, Vol. 35, No. 6: June, 1963. p. 799.

18. Culp, Russel L., and Ralph E. Roderick. "The Lake Tahoe Water Reclamation Plant," JWPCF: February, 1966. p. 147.

19. Dryden, Franklin D. "Demineralization of Reclaimed Waters," *J/Industrial Wastes Engineering*: August/September, 1971.

20. Eastern Municipal Water District. *Study of Reutilization of Wastewater Recycled Through Ground Water*. EPA, Water Pollution Control Research Report Series No. 16060DDZ07/71, Vol. I: July, 1971.

21. Fuhrman, Ralph E. "*The Potential for Reuse of Wastewater as a Source of Water Supply*." Presented at the American Water Works Association Conference in Chicago, Illinois: June 7, 1972.

22. Gavis, J. *Wastewater Reuse*. National Water Commission, NWC-EES-71-003: 1971.

23. Gomez, H. J. "Water Reuse in Monterrey, Mexico," *JWPCF*, Vol. 40, No. 4: April, 1968. p. 540.

24. Haney, P. D., and C. L. Hamann. "Dual Water Systems," *JAWWA*, Vol. 57, No. 9. p. 1073.

25. Hansen, C. A. "Standards for Drinking Water and Direct Reuse," *Water and Wastes Engineering*, Vol. 6, No. 4: April, 1969.

26. Horstkotte, G. A., D. G. Niles, D. S. Parker, and D. H. Caldwell. "*Full Scale Testing of a Water Reclamation System*." Presented at 45th W.P.C.F. Conference, Atlanta, Georgia: 1972.

27. Irving, C. E. "How One City Sells its Sludge," *Compost Science*: Spring, 1960. pp. 18-20.

28. Isaac, P. C. G., and I. Vahidi. "The Recovery of Alum Sludge," *Proc. Soc. Wat. Treatm. and Exam.*, Vol. 10: 1961. p. 91.

29. Jimeno, Francisco J. *Reclaimed Effluent in Golf Course Irrigation*. Mexico City, Mexico.

30. Kiess, I. F. "Combined Sludge-Garbage Composting," Compost Science: Summer, 1962. pp. 13-14.

31. Kreusch, Ed, and Ken Schmidt. Wastewater Demineralization by Ion Exchange. Project No. 17040 EEE, Contract No. 14-12-599, Office of Research and Monitoring, Environmental Protection Agency: December, 1971.

32. Lambie, John A. Progress Report, Demonstration Project Grant No. WPD 50-03-66: Waste Water Reclamation Project for Antelope Valley, California. Los Angeles, Calif.: May 1, 1967.

33. Leaver, R. E. "Marketing Sewage Sludge in the Northwest," Compost Science: Spring, 1961. pp. 44-47.

34. Long, William N., and Frank A. Bell, Jr. "Health Factors and Reused Water," Journal American Water Works Association, Vol. 64: April, 1972. pp. 220-225.

35. Lusczynski, N. J., and W. V. Swarzenski. Salt-Water Enchroachment in Southern Nassau and Southeastern Queens Counties, Long Island, New York. U.S. Geol. Survey, Water Supply Paper 1613-F: 1966. 76 pp.

36. Moyer, Harlan E. "The South Lake Tahoe Water Reclamation Project," Public Works: December, 1968.

37. Melbourne and Metropolitan Board of Works. Waste into Wealth. Melbourne, Australia: 1971.

38. Merrell, John C., Jr., Albert Katko, and Herbert E. Pintler. The Santee Recreation Project, Santee, California. Summary Report , Public Health Service Publication No. 99-WP-27: December, 1965.

39. Mitchell, J. K., and W. R. Samples. Report on Reclamation of Wastewater for Well Injection. Los Angeles County Flood Control District, Los Angeles, Calif.: 1967.

40. Morris, J. Carrell. "Chlorination and Disinfection--State of the Art," JAWWA, No. 63: December, 1971. p. 769.

41. Muskegon County Board and Department of Public Works, Muskegon, Michigan. Engineering Feasibility Demonstration Study for Muskegon County, Michigan: Wastewater Treatment-Irrigation System. Federal Water Quality Administration Program No. 11010 FMY: September, 1970.

42. North Star Research and Development Institute. New and Ultrathin Membranes for Municipal Wastewater Treatment by Reverse Osmosis. FWQA Project No. 17020 EFA, Contract No. 14-12-587.

43. Nuper and Stander. "The Virus Problem in the Windhoek Wastewater Reclamation Project." Presented at the 6th International Water Pollution Research Meeting: June, 1972.

44. Parizek, R. R., et al. "Waste Water Renovation and Conservation," The Pennsylvania State University Studies No. 23, University Park, Pa.: 1967.

45. Pennypacker, Stanley, William E. Sopper, and Louis T. Kardos. "Renovation of Wastewater Effluent by Irrigation of Forest Land."

46. Peters, J. H., and J. L. Rose. "Water Conservation by Reclamation and Recharge," Am. Soc. Civ. Eng. Jour., San. Div., Vol. 94, SA4: 1968. pp. 625-639.

47. "Recycling Sludge and Sewage Effluent by Land Disposal," Environmental Science and Technology, Vol. 6, No. 10: October, 1972.

48. Reuse of Wastewater in Germany. OECD, Paris: 1969.

49. Rex Chainbelt Inc., Ecology Division. Amenability of Reverse Osmosis Concentrate to Activated Sludge Treatment. Environmental Protection Agency Project No. 17040 EUE: July, 1971.

50. Roberts, J. M., and C. P. Roddy. "Recovery and Reuse of Alum Sludge at Tampa," JAWWA, Vol. 52: July, 1960. p. 857.

51. Standard Methods for the Examination of Water and Wastewater. APHA, AWWA, WPCF-Thirteenth Edition: 1971.

52. State of California, The Resources Agency, State Water Quality Control Board. Wastewater Reclamation at Whittier Narrows. Sacramento, Calif. Publication No. 33: 1966. 99 pp.

53. Stephan, David G., et al. "Wastewater Treatment and Renovation Status of Process Development," JWPCF, Vol. 42: 1970. p. 339.

54. Stevens, R. M., and the Center for the Study of Federalism. Green Land--Clean Streams: The Beneficial Use of Waste Water Through Land Treatment. Temple University, Philadelphia, Pennsylvania: 1972.

55. Symons, George E. "Water Reuse--What Do We Mean?", Water and Wastes Engineering, Vol. 5, No. 6: June, 1968.

56. Sawyer, George A. "New Trends in Wastewater Treatment," Chemical Engineering: July 24, 1972. p. 120.

57. Seabrook, Belford L. Irrigation of Liquid Digested Sludge: An Alternative Technique.

58. Slechta, Alfred, and Gordon Culp. Plant Scale Regeneration of Granular Activated Carbon. Public Health Service Demonstration Grant 84-01: February, 1966.

59. Slechta, Alfred, and Gordon Culp. Recovery and Reuse of Coagulant from Treated Sewage. Public Health Service Demonstration Grant 85-01: February, 1966.

60. Smith, Clinton E. "Use and Reuse of Lime in Removing Phosphorus and Nitrogen from Wastewater." Presented at 67th Annual Convention of the National Lime Association, Phoenix, Ariz.: April 10-11, 1969.

61. Southern Research Institute. Demineralization of Wastewater by the Transport-Depletion Process. Environmental Protection Agency Project No. 17040 EUN, Contract No. 14-12-812: February, 1971.

62. Task Group 2440-R on Artificial Ground-Water Recharge. "Experience with Injection Wells for Artificial Ground-Water Recharge," JAWWA, Vol. 57, No. 5: 1965. pp. 629-639.

63. Tchobanoglous, George, Rolf Eliassen, and George E. Bennett. Progress Report, Water Reclamation Study Program: Demonstration Project Grant No. WPD 21-05. Stanford University, Stanford, California: October, 1967.

64. Use of Reclaimed Wastewaters as a Public Water Supply Source. AWWA Policy Statement, JAWWA Yearbook, Vol. 63, No. 11. p. 55

65. University of Florida. Feasibility of Treating Wastewater by Distillation. Environmental Protection Agency Project No. 17040 DNM, Contract No. 14-12-571, Gainesville, Florida: February, 1971.

66. Van Vuuren, L. R. J., M. R. Henzen, G. J. Stander, and A. J. Clayton. The Full-Scale Reclamation of Purified Sewage Effluent for the Augmentation of the Domestic Supplies of the City of Windhoek. Advances in Water Pollution Research, Pergamon Press: 1970.

APPENDIX B - COST-EFFECTIVENESS ANALYSIS GUIDELINES (40 CFR 35 - APPENDIX A)

federal register

Title 40—Protection of the Environment

CHAPTER I—ENVIRONMENTAL PROTECTION AGENCY

SUBCHAPTER D—GRANTS

PART 35—STATE AND LOCAL ASSISTANCE

Appendix A—Cost-Effectiveness Analysis

On July 3, 1973, notice was published in the FEDERAL REGISTER that the Environmental Protection Agency was proposing guidelines on cost-effectiveness analysis pursuant to section 212(2) (c) of the Federal Water Pollution Act Amendments of 1972 (the Act) to be published as appendix A to 40 CFR part 35.

Written comments on the proposed rulemaking were invited and received from interested parties. The Environmental Protection Agency has carefully considered all comments received. No changes were made in the guidelines as earlier proposed. All written comments are on file with the agency.

Effective date.—These regulations shall become effective October 10, 1973.

Dated September 4, 1973.

JOHN QUARLES,
Acting Administrator.

APPENDIX A

COST EFFECTIVENESS ANALYSIS GUIDELINES

a. *Purpose.*—These guidelines provide a basic methodology for determining the most cost-effective waste treatment management system or the most cost-effective component part of any waste treatment management system.

b. *Authority.*—The guidelines contained herein are provided pursuant to section 212 (2) (C) of the Federal Water Pollution Control Act Amendments of 1972 (the Act).

c. *Applicability.*—These guidelines apply to the development of plans for and the selection of component parts of a waste treatment management system for which a Federal grant is awarded under 40 CFR, Part 35.

d. *Definitions.*—Definitions of terms used in these guidelines are as follows:

(1) *Waste treatment management system.*—A system used to restore the integrity of the Nation's waters. Waste treatment management system is used synonymously with "treatment works" as defined in 40 CFR, Part 35.905–15.

(2) *Cost-effectiveness analysis.*—An analysis performed to determine which waste treatment management system or component part thereof will result in the minimum total resources costs over time to meet the Federal, State or local requirements.

(3) *Planning period.*—The period over which a waste treatment management system is evaluated for cost-effectiveness. The planning period commences with the initial operation of the system.

(4) *Service life.*—The period of time during which a component of a waste treatment management system will be capable of performing a function.

(5) *Useful life.*—The period of time during which a component of a waste treatment management system will be required to perform a function which is necessary to the system's operation.

e. *Identification, selection and screening of alternatives*—(1) *Identification of alternatives.*—All feasible alternative waste management systems shall be initially identified. These alternatives should include systems discharging to receiving waters, systems using land or subsurface disposal techniques, and systems employing the reuse of wastewater. In identifying alternatives, the possibility of staged development of the system shall be considered.

(2) *Screening of alternatives.*—The identified alternatives shall be systematically screened to define those capable of meeting the applicable Federal, State, and local criteria.

(3) *Selection of alternatives.*—The screened alternatives shall be initially analyzed to determine which systems have cost-effective potential and which should be fully evaluated according to the cost-effectiveness analysis procedures established in these guidelines.

(4) *Extent of effort.*—The extent of effort and the level of sophistication used in the cost-effectiveness analysis should reflect the size and importance of the project.

f. *Cost-Effective analysis procedures*—(1) *Method of Analysis.*—The resources costs shall be evaluated through the use of opportunity costs. For those resources that can be expressed in monetary terms, the interest (discount) rate established in section (f) (5) will be used. Monetary costs shall be calculated in terms of present worth values or equivalent annual values over the planning period as defined in section (f) (2). Nonmonetary factors (e.g., social and environmental) shall be accounted for descriptively in the analysis in order to determine their significance and impact.

The most cost-effective alternative shall be the waste treatment management system determined from the analysis to have the lowest present worth and/or equivalent annual value without overriding adverse nonmonetary costs and to realize at least identical minimum benefits in terms of applicable Federal, State, and local standards for effluent quality, water quality, water reuse and/or land and subsurface disposal.

(2) *Planning period.*—The planning period for the cost-effectiveness analysis shall be 20 years.

(3) *Elements of cost.*—The costs to be considered shall include the total values of the resources attributable to the waste treatment management system or to one of its component parts. To determine these values, all monies necessary for capital construction costs and operation and maintenance costs shall be identified.

Capital construction costs used in a cost-effectiveness analysis shall include all contractors' costs of construction including overhead and profit; costs of land, relocation, and right-of-way and easement acquisition; design engineering, field exploration, and engineering services during construction; administrative and legal services including costs of bond sales; startup costs such as operator training; and interest during construction. Contingency allowances consistent with the level of complexity and detail of the cost estimates shall be included.

Annual costs for operation and maintenance (including routine replacement of equipment and equipment parts) shall be included in the cost-effectiveness analysis. These costs shall be adequate to ensure effective and dependable operation during the planning period for the system. Annual costs shall be divided between fixed annual costs and costs which would be dependent on the annual quantity of wastewater collected and treated.

(4) *Prices.*—The various components of cost shall be calculated on the basis of market prices prevailing at the time of the cost-effectiveness analysis. Inflation of wages and prices shall not be considered in the analysis. The implied assumption is that all prices involved will tend to change over time by approximately the same percentage. Thus, the results of the cost effectiveness analysis will not be affected by changes in the general level of prices.

Exceptions to the foregoing can be made if their is justification for expecting significant changes in the relative prices of certain items during the planning period. If such cases are identified, the expected change in these prices should be made to reflect their future relative deviation from the general price level.

(5) *Interest (discount) rate.*—A rate of 7 percent per year will be used for the cost-effectiveness analysis until the promulgation of the Water Resources Council's "Proposed Principles and Standards for Planning Water and Related Land Resources." After promulgation of the above regulation, the rate established for water resource projects shall be used for the cost-effectiveness analysis.

(6) *Interest during construction.*—In cases where capital expenditures can be expected to be fairly uniform during the construction period, interest during construction may be calculated as $I \times \frac{1}{2} P \times C$ where:

I=the interest (discount) rate in Section f(5).
P=the construction period in years.
C=the total capital expenditures.

In cases when expenditures will not be uniform, or when the construction period will be greater than three years, interest during construction shall be calculated on a year-by-year basis.

(7) *Service life.*—The service life of treatment works for a cost-effectiveness analysis shall be as follows:

Land	Permanent
Structures (includes plant buildings, concrete process tankage, basins, etc.; sewage collection and conveyance pipelines; lift station structures; tunnels; outfalls)	30–50 years
Process equipment (includes major process equipment such as clarifier mechanism, vacuum filters, etc.; steel process tankage and chemical storage facilities; electrical generating facilities on standby service only).	15–20 years
Auxiliary equipment (includes instruments and control facilities; sewage pumps and electric motors; mechanical equipment such as compressors, aeration systems, centrifuges, chlorinators, etc.; electrical generating facilities on regular service).	10–15 years

Other service life periods will be acceptable when sufficient justification can be provided.

Where a system or a component is for interim service and the anticipated useful life is less than the service life, the useful life shall be substituted for the service life of the facility in the analysis.

(8) *Salvage value.*—Land for treatment works, including land used as part of the treatment process or for ultimate disposal of residues, shall be assumed to have a salvage value at the end of the planning period equal to its prevailing market value at the time of the analysis. Right-of-way easements shall be considered to have a salvage value not greater than the prevailing market value at the time of the analysis.

Structures will be assumed to have a salvage value if there is a use for such structures at the end of the planning period. In this case, salvage value shall be estimated using straightline depreciation during the service life of the treatment works.

For phased additions of process equipment and auxiliary equipment, salvage value at the end of the planning period may be estimated under the same conditions and on the same basis as described above for structures.

When the anticipated useful life of a facility is less than 20 years (for analysis of interim facilities), salvage value can be claimed for equipment where it can be clearly demonstrated that a specific market or reuse opportunity will exist.

[FR Doc.73-19104 Filed 9-7-73;8:45 am]

126<

APPENDIX C - SECONDARY TREATMENT INFORMATION (40 CFR 133)

federal register

FRIDAY, AUGUST 17, 1973
WASHINGTON, D.C.

Volume 38 ■ Number 159

PART II

THE NATIONAL ARCHIVES OF THE UNITED STATES • 1934 •

ENVIRONMENTAL PROTECTION AGENCY

■

WATER PROGRAMS

Secondary Treatment Information

Title 40—Protection of Environment

CHAPTER I—ENVIRONMENTAL PROTECTION AGENCY

SUBCHAPTER D—WATER PROGRAMS

PART 133—SECONDARY TREATMENT INFORMATION

On April 30, 1973, notice was published in the FEDERAL REGISTER that the Environmental Protection Agency was proposing information on secondary treatment pursuant to section 304(d)(1) of the Federal Water Pollution Control Act Amendments of 1972 (the Act). Reference should be made to the preamble of the proposed rulemaking for a description of the purposes and intended use of the regulation.

Written comments on the proposed rulemaking were invited and received from interested parties. The Environmental Protection Agency has carefully considered all comments received. All written comments are on file with the Agency.

The regulation has been reorganized and rewritten to improve clarity. Major changes that were made as a result of comments received are summarized below:

(a) The terms "1-week" and "1-month" as used in § 133.102 (a) and (b) of the proposed rulemaking have been changed to 7 consecutive days and 30 consecutive days respectively (See § 133.102 (a), (b), and (c)).

(b) Some comments indicated that the proposed rulemaking appeared to require 85 percent removal of biochemical oxygen demand and suspended solids only in cases when a treatment works would treat a substantial portion of extremely high strength industrial waste (See § 133.102(g) of the proposed rulemaking). The intent was that in no case should the percentage removal of biochemical oxygen demand and suspended solids in a 30 day period be less than 85 percent. This has been clarified in the regulation. In addition, it has been expressed as percent remaining rather than percent removal calculated using the arithmetic means of the values for influent and effluent samples collected in a 30 day period (See § 133.102(a) and (b)).

(c) Comments were made as to the difficulty of achieving 85 percent removal of biochemical oxygen demand and suspended solids during wet weather for treatment works receiving flows from combined sewer systems. Recognizing this, a paragraph was added which will allow waiver or adjustment of that requirement on a case-by-case basis (See § 133.103(a)).

(d) The definition of a 24-hour composite sample (See § 133.102(c) of the proposed rulemaking) was deleted from the regulation. The sampling requirements for publicly owned treatment works will be established in guidelines issued pursuant to sections 304(g) and 402 of the Act.

(e) In § 133.103 of the proposed rulemaking, it was recognized that secondary treatment processes are subject to upsets over which little or no control may be exercised. This provision has been deleted. It is no longer considered necessary in this regulation since procedures for notice and review of upset incidents will be included in discharge permits issued pursuant to section 402 of the Act.

(f) Paragraph (f) of § 133.102 of the proposed rulemaking, which relates to treatment works which receive substantial portions of high strength industrial wastes, has been rewritten for clarity. In addition, a provision has been added which limits the use of the upwards adjustment provision to only those cases in which the flow or loading from an industry category exceeds 10 percent of the design flow or loading of the treatment works. This intended to reduce or eliminate the administrative burden which would be involved in making insignificant adjustments in the biochemical oxygen demand and suspended solids criteria (See § 133.103(b)).

The major comments for which changes were not made are discussed below:

(a) Comments were received which recommended that the regulation be written to allow effluent limitations to be based on the treatment necessary to meet water quality standards. No change has been made in the regulations because the Act and its legislative history clearly show that the regulation is to be based on the capabilities of secondary treatment technology and not ambient water quality effects.

(b) A number of comments were received which pointed out that waste stabilization ponds alone are not generally capable of achieving the proposed effluent quality in terms of suspended solids and fecal coliform bacteria. A few commenters expressed the opposite view. The Agency is of the opinion that with proper design (including solids separation processes and disinfection in some cases) and operation, the level of effluent quality specified can be achieved with waste stabilization ponds. A technical bulletin will be published in the near future which will provide guidance on the design and operation of waste stabilization ponds.

(c) Disinfection must be employed in order to achieve the fecal coliform bacteria levels specified. A few commenters argued that disinfectant is not a secondary treatment process and therefore the fecal coliform bacteria requirements should be deleted. No changes were made because disinfection is considered by the Agency to be an important element of secondary treatment which is necessary for protection of public health (See § 133.102(c)).

Effective date. These regulations shall become effective on August 17, 1973.

JOHN QUARLES,
Acting Administrator.

AUGUST 14, 1973.

Chapter I of title 40 of the Code of Federal Regulations is amended by adding a new Part 133 as follows:

Sec.
133.100 Purpose.
133.101 Authority.
133.102 Secondary treatment.
133.103 Special considerations.
133.104 Sampling and test procedures.

AUTHORITY: Secs. 304()(1), 301(b)(1)(B), Federal Water Pollution Control Act Amendments, 1972, P.L. 92-500.

§ 133.100 Purpose.

This part provides information on the level of effluent quality attainable through the application of secondary treatment.

§ 133.101 Authority.

The information contained in this Part is provided pursuant to sections 304(d)(1) and 301(b)(1)(B) of the Federal Water Pollution Control Act Amendments of 1972, PL 92-500 (the Act).

§ 133.102 Secondary treatment.

The following paragraphs describe the minimum level of effluent quality attainable by secondary treatment in terms of the parameters biochemical oxygen demand, suspended solids, fecal coliform bacteria and pH. All requirements for each parameter shall be achieved except as provided for in § 133.103.

(a) *Biochemical oxygen demand (five-day).* (1) The arithmetic mean of the values for effluent samples collected in a period of 30 consecutive days shall not exceed 30 milligrams per liter.

(2) The arithmetic mean of the values for effluent samples collected in a period of seven consecutive days shall not exceed 45 milligrams per liter.

(3) The arithmetic mean of the values for effluent samples collected in a period of 30 consecutive days shall not exceed 15 percent of the arithmetic mean of the values for influent samples collected at approximately the same times during the same period (85 percent removal).

(b) *Suspended solids.* (1) The arithmetic mean of the values for effluent samples collected in a period of 30 consecutive days shall not exceed 30 milligrams per liter.

(2) The arithmetic mean of the values for effluent samples collected in a period of seven consecutive days shall not exceed 45 milligrams per liter.

(3) The arithmetic mean of the values for effluent samples collected in a period of 30 consecutive days shall not exceed 15 percent of the arithmetic mean of the values for influent samples collected at approximately the same times during the same period (85 percent removal).

(c) *Fecal coliform bacteria.* (1) The geometric mean of the value for effluent samples collected in a period of 30 consecutive days shall not exceed 200 per 100 milliliters.

(2) The geometric mean of the values for effluent samples collected in a period of seven consecutive days shall not exceed 400 per 100 milliliters.

(d) *pH*. The effluent values for pH shall remain within the limits of 6.0 to 9.0.

§ 133.103 Special considerations.

(a) *Combined sewers*. Secondary treatment may not be capable of meeting the percentage removal requirements of paragraphs (a)(3) and (b)(3) of § 133.102 during wet weather in treatment works which receive flows from combined sewers (sewers which are designed to transport both storm water and sanitary sewage). For such treatment works, the decision must be made on a case-by-case basis as to whether any attainable percentage removal level can be defined, and if so, what that level should be.

(b) *Industrial wastes*. For certain industrial categories, the discharge to navigable waters of biochemical oxygen demand and suspended solids permitted under sections 301(b)(1)(A)(i) or 306 of the Act may be less stringent than the values given in paragraphs (a)(1) and (b)(1) of § 133.102. In cases when wastes would be introduced from such an industrial category into a publicly owned treatment works, the values for biochemical oxygen demand and suspended solids in paragraphs (a)(1) and (b)(1) of § 133.102 may be adjusted upwards provided that: (1) the permitted discharge of such pollutants, attributable to the industrial category, would not be greater than that which would be permitted under sections 301(b)(1)(a)(i) or 306 of the Act if such industrial category were to discharge directly into the navigable waters, and (2) the flow or loading of such pollutants introduced by the industrial category exceeds 10 percent of the design flow or loading of the publicly owned treatment works. When such an adjustment is made, the values for biochemical oxygen demand or suspended solids in paragraphs (a)(2) and (b)(2) of § 133.102 should be adjusted proportionally.

§ 133.104 Sampling and test procedures.

(a) Sampling and test procedures for pollutants listed in § 133.102 shall be in accordance with guidelines promulgated by the Administrator pursuant to sections 304(g) and 402 of the Act.

(b) Chemical oxygen demand (COD) or total organic carbon (TOC) may be substituted for biochemical oxygen demand (BOD) when a long-term BOD:COD or BOD:TOC correlation has been demonstrated.

[FR Doc.73-17194 Filed 8-16-73;8:45 am]